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ERRATA.

Page 209, line 41, for " ICHNEUMONIDAE " read " BRACONIDAE "
,, 276, line 38, for " *Aphrostocetus* " read " *Aprostocetus* "
,, 426, legend to fig. 3, for " fully grown larva " read " nearly mature larva "
,, 427, legend to fig. 4, for " spiracles of larva " read " hinder end of nearly mature larva, showing posterior stigmatic plates "
,, 428, legend to fig. 5, for " dorsal view " read " ventral view "
,, 548, line 1, for " *Leptocryptes* " read " *Leptocryptus* "

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THE CRAMBINE GENERA *DIATRAEA* AND *XANTHOPHERNE* (LEP., PYRAL.).

By HAROLD E. BOX, F.E.S.

(PLATES I—V.)

Introduction.

The present paper is the result of studies begun privately by the writer shortly after his return from South America in February 1930. The subsequent continuation and conclusion of the task was made possible through the authorities of the Imperial Institute of Entomology, to whom, especially the Director, Sir Guy A. K. Marshall, C.M.G., F.R.S., the writer is gratefully indebted for his appointment, in a temporary capacity, at the Farnham House Laboratory, as from 1st August. It was considered that a final revision of the American forms of the groups here considered would be a useful contribution to the West Indian investigations on sugar-cane insects being conducted on behalf of the Institute by Dr. J. G. Myers. At the laboratory the writer found conditions ideal for the prosecution of such work, and he desires to acknowledge his appreciation of the continuous help and encouragement received from the Superintendent, Dr. W. R. Thompson, and his colleagues there, among whom Dr. G. Salt deserves a special word of thanks for his never-failing generosity in offering friendly advice and practical aid, both of which, it must be confessed, have been frequently needed.

Such a work as the present would not have been possible without the valued co-operation of those who have been kind enough to furnish the material for study. The great majority of the specimens examined, which amount in all to 1,290, were found in the British Museum and the Tring Museum, the authorities of both of which institutions granted the writer *carte blanche* to work upon their collections. Mr. W. H. T. Tams, of the former, freely gave the writer the benefit of his experience and has collaborated in the progress of these studies since their commencement; the writer is further indebted to Mr. Tams for devoting many hours of his own time to the preparation of the micro-photographs of the genitalia. To Lord Rothschild and Dr. Karl Jordan the writer's most respectful thanks are tended, not only for permission to work upon the very considerable number of specimens in the Tring Museum, but also for granting unusual facilities in the way of laboratory space and loan of instruments, reagents, etc., over a period of several weeks, during which time nearly 200 separate mounts of genitalia were prepared and studied at Tring.

Professor E. B. Poulton very kindly gave the writer permission to look over the collections of the Hope Department of Zoology in the University of Oxford, and personally aided in the search, with the result that further interesting specimens and records were discovered.

Sir Guy Marshall has been good enough to hand over to the writer several collections of *Diatraea* which had been received by the Institute from time to time, including long series of several species reared from sugar-cane in the West Indies by Dr. Myers and Mr. R. W. E. Tucker. Mr. H. T. Osborn, Entomologist of the Central Aguirre Sugar Company, Porto Rico, sent a valuable series of several species which he had reared from larvae found in sugar-cane in Venezuela, Santo Domingo and Porto Rico. Recently, a collection of *Diatraea*, bred from known female parents (included) in Trinidad by Mr. F. W. Urich, has been lent to the writer by Dr. Thompson.

Through Mr. Tams, the writer has been able to examine all of the specimens of *Diatraea* in the Zoological Museum of the University of Berlin, these having been forwarded through the kindness of Dr. Martin Hering.

Among the collections in the institutions named are several of great historical interest, the following being worthy of special mention : the Felder collection in the Tring Museum; the Zeller, Grote, Walsingham and Godman-Salvin* collections in the British Museum ; and the Staudinger collection in the Berlin Museum. In these, all specimens of *Diatraea* have now been revised and determination labels attached.

Throughout the course of the work the writer has kept in touch, by means of correspondence, with Dr. Carl Heinrich, of the United States Bureau of Entomology, and is particularly grateful to him for most kindly sending on loan or as a gift from the U.S. National Museum certain paratypes and other specimens, the examination of which was necessary to determine some of the more difficult species. Dr. Heinrich also most obligingly examined and reported upon a number of provisionally identified specimens which the writer sent to him for comparison with types at Washington. Several of the most important sections of the present memoir could not have been completed without the help thus rendered by Dr. Heinrich, to whom the writer offers his sincere thanks.

Two other personal friends of the writer are gratefully accredited with substantially aiding this work : Mr. A. J. Engel Terzi by inking-in and giving the final touches to text-figures 2, 3 and 4, and Mr. Louis Nell by translating from the original German all those parts of Zeller's several papers which contain references to *Diatraea* and allied genera.

The genus *Diatraea* includes a large number of moths whose larvae are borers in the stalks of graminaceous and cyperaceous plants. About 90 species are at present recognised, distributed throughout the tropical and subtropical regions of both hemispheres ; some of them have been known for many years as major pests of sugar-cane, corn or maize, rice, and other cultivated grasses.

Many treatises have been published upon the economic and ecological aspects of different species of *Diatraea* in various parts of the world, but owing to the habits of these insects no effective measures for reducing their numbers have yet been devised. Various recommendations, for the most part preventive, have been made for over a century, but it is only during recent years that the application of biological methods has been seriously considered as a possible means of control. A large number of Hymenopterous and Dipterous parasites, as well as numerous

* The details of the Godman-Salvin collection were published in the " Biologia Centrali-Americana." It has been found that the various references to *Diatraea* in that work are for the most part unreliable, owing to inaccurate determinations of the specimens. In the present paper corrections to the Biologia appear wherever necessary.

predators, are known to attack the early stages of several species of *Diatraea* in different countries. Already attempts have been and are being made to effect the introduction of certain of these from one country to another, but though definite establishments of imported parasites have been secured from time to time, no conspicuous success has yet been obtained in any instance. This may be largely due to the fact that until very recently no definite organised researches have been conducted to ascertain the inter-relations between the different species of *Diatraea*, their food-plants and their natural enemies. Such investigations, on behalf of the Empire, are included among the projects initiated by the Farnham House Laboratory, and already some most valuable and suggestive results have followed Dr. Myers' preliminary explorations in the West Indies and British Guiana.

It will immediately become apparent that a taxonomic revision of the group concerned is a most desirable, if not absolutely necessary, prelude to such research. In the present work the writer has also kept in mind the needs of the isolated field worker who is chiefly interested in having a ready means of identifying his specimens correctly.

The value of the numerous references to *Diatraea* to be found in the literature of economic entomology is greatly diminished owing to the fact that, prior to the publication in 1927 of Dyar & Heinrich's revision of the American forms then known,* the state of the nomenclature was little less than chaotic. These authors were the first to make a detailed study of the genitalia and to use the characters of these organs in specific diagnoses, with the result that the earlier classifications underwent a complete metamorphosis, leading to entirely new species-concepts.

A similar revision still awaits the extra-American species which have been described in or referred to *Diatraea*, and to judge by a few preliminary studies that have been made upon some African and Oriental forms, it is very probable that eventually the group will be divided and the generic name *Diatraea* retained for the American species only. It is to be observed that, whereas no consistent external morphological characters have been noted as yet upon which such a division might logically be based, the genitalia of the Old World species are very different from those of the forms discussed in the present paper, and sufficiently so to warrant their consideration as an important factor in generic differentiation. Nevertheless, whilst admitting the desirability of limiting *Diatraea* in the manner suggested, the writer does not think that the investigation has yet proceeded far enough to justify such a change ; a critical study of the genitalia of all the known Ethiopian, Oriental and Australasian species is required, together with a thorough examination of the voluminous literature concerning them.

Of the 32 American species of *Diatraea* recognised by Dyar & Heinrich,† one is here considered synonymous with *saccharalis*, Fabr., and the names of two others have been changed to meet the requirements of priority rules, the names here adopted for these having been hitherto erroneously considered as synonyms of other species. Two allied genera recognised by those authors are here merged into *Diatraea*, the definition of which is accordingly modified ; four species are thus added to the genus. Two species which were known to Dyar & Heinrich by description only, and consequently excluded from their revision, are included in the present paper, together with one described since and ten others here named and described for the first time.

The inclusion of *Xanthopherne* in the present paper is admittedly largely accidental, but nevertheless it is not inconvenient that the genus should receive attention here

* "The American Moths of the Genus *Diatraea* and Allies."—Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, pp. 1–48, ff. 1–82.

† Hampson (1895) recognised but 3 species ; Dyar (1911) dealt with 18 species and 5 subspecies.

owing to the possible confusion of some of the species with *Diatraea*, though *Xanthopherne* is probably more closely related to *Doratoperas*, Hamps., than to that genus, in spite of the similar venation. Other Crambine genera with the *Diatraea* type of venation are indicated by Dyar & Heinrich in their key, but all differ from *Diatraea* and *Xanthopherne* by the presence of ocelli.

*Key to the Genera here considered.**

" Fore wing with vein 7 from cell; vein 11 anastomosing with 12." Ocelli absent.

1. Maxillary palpi long, at least three times the length of the head; much longer than labial palpi. Male genitalia with the " uncus normally triangular, with apex pointed or broadened, sometimes greatly broadened; gnathos normally triangular (beak-like), with more or less spining towards apex; greatly broadened towards apex only when uncus is similarly modified."
Diatraea, Guilding.

2. Maxillary palpi short, at most twice the length of the head; not much longer than the labial palpi. Male genitalia with the " uncus laterally compressed and greatly developed; gnathos hook-like and very heavy, unspined."
Xanthopherne, Dyar & Heinrich.

Four species are here referred to *Xanthopherne*, one of them having been described originally in *Diatraea*.

Geographical Distribution.

The material upon which the present paper is based is, for the most part, the result of numerous individual collections made casually from time to time by entomologists who were not particularly interested in securing data relative to one genus, or even one family, of Lepidoptera. Nevertheless, it has thrown considerable light on the distribution of several species hitherto known from only one, or perhaps two, restricted localities. But Science would benefit most if it were possible for a thorough study to be made over a reasonable period of time in a limited area, where the numerical relationships between the predominant and less obtrusive forms could be studied in relation to environmental and seasonal factors. The correlation of the distribution of several species inhabiting a given locality with that of their food-plants, and the elucidation of problems concerning the insects in a virgin plant-association, would add more to our knowledge and lead to a more rational classification of species than the continual examination of casually collected specimens.

In spite of the great interest this aspect of the subject has for the writer, he feels the need to hesitate before drawing definite conclusions upon the available data, because of their limitations. Little comment is needed upon the accompanying table, which shows at a glance the state of our knowledge in regard to the distribution of the 48 American species of *Diatraea*. From this we are justified in concluding that, among American species, *D. saccharalis* and *D. lineolata* are not only numerically (over their whole range and for all times) the most abundant species, but that they are also the most widely distributed in the genus (see also fig. 1). Several instances are on record, however, where another species predominates in the zone inhabited by *saccharalis* or *lineolata*, or both, *e.g.*, *D. dyari* in Northern Argentina, *D. impersonatella* in parts of Trinidad, etc., or occasionally it may happen that the dominance of the second (or third) species may be provisional, for a limited season or a short succession of seasons only. The choice of food-plants might reasonably be expected to exert a powerful influence upon the spread of a species, but cases are before us where it is clear that some other unknown factors are responsible.

* The quoted sections of this key are taken from the publication of Dyar & Heinrich.

TABLE I —*Showing the Distribution, by Countries, of the American Species of* Diatraea

	Bahamas	Cuba	Jamaica	Haiti—St Domingo	Porto Rico	Virgin Islands	Antigua—St Kitts	Guadeloupe	Dominica	Martinique	St Lucia	Barbados	St Vincent	Grenada	Tobago	Trinidad	Venezuela	British Guiana	Dutch Guiana	French Guiana	Brazil	Paraguay	Argentina	Bolivia	Peru	Ecuador	Colombia	Panama	Costa Rica	Honduras	Guatemala	British Honduras	Mexico	U S A
albicrinella																		x			x				x	x								
amazonica																					x		x											
amnemonella																					x													
anathericola																		x			x													
angustella																					x	?	?											
argentina																							x											
bellifactella														x		x					x			x	x									
brunnescens																	x																	
busckella																	x										x	x						
canella														x	x	x	x	x	x	x														
castrensis																					x													
cavenella																				x	x													
continens																					x		x											
crambidoides																																		x
dyari																							x											
entreriana																							x											
evanescens																															x			x
flavipennella																					x													
fuscella																													x		x		x	
[illegible]a																												x						
[illegible]osella																																	x	
[illegible]lella																													x					
guatemalella																													x		x		x	
impersonatella																x	x	x	x		x	?	x	?										
incertella																					x													
indigenella																											x							
instructella																																	x	
lentistrialis																							x											
lineolata	x	x												x		x	x	x	x	x						x	x	x	x		x	x	x	
lisetta																												x					x	x
luteella																										x								
magnifactella																																	x	
maronialis																				x	x													
minimifacta																x	x			x														
m[illegible]obe																															x		x	
muellerella																																	x	
obliqualis																							x											
pallidostricta																					x													
pedibarbata																		x	x	x			x											
postlineella																															x			
rufescens																								x										
saccharalis	?	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x
schausella																											x				x			
strigipennella																					x													
suffusella																	x			x														
tabernella																											x	x				x		
umbrialis																				x														
venosalis																																		x

Granted equal chances of dispersal by natural or artificial means, it is very difficult to explain the extraordinary scarcity of *D. impersonatella* in the canefields of British Guiana, compared with the abundance of two other species, *saccharalis* and *canella*, in the same country, when it is realised that all three species also occur in Trinidad, where *impersonatella* has been found predominant. A somewhat similar case might be cited in *D. dyari* in Argentina. All the factors which appear to be necessary for its successful establishment seem to be present in the canefields of the Province of Tucuman, yet it does not occur there, while in the neighbouring territories of Salta

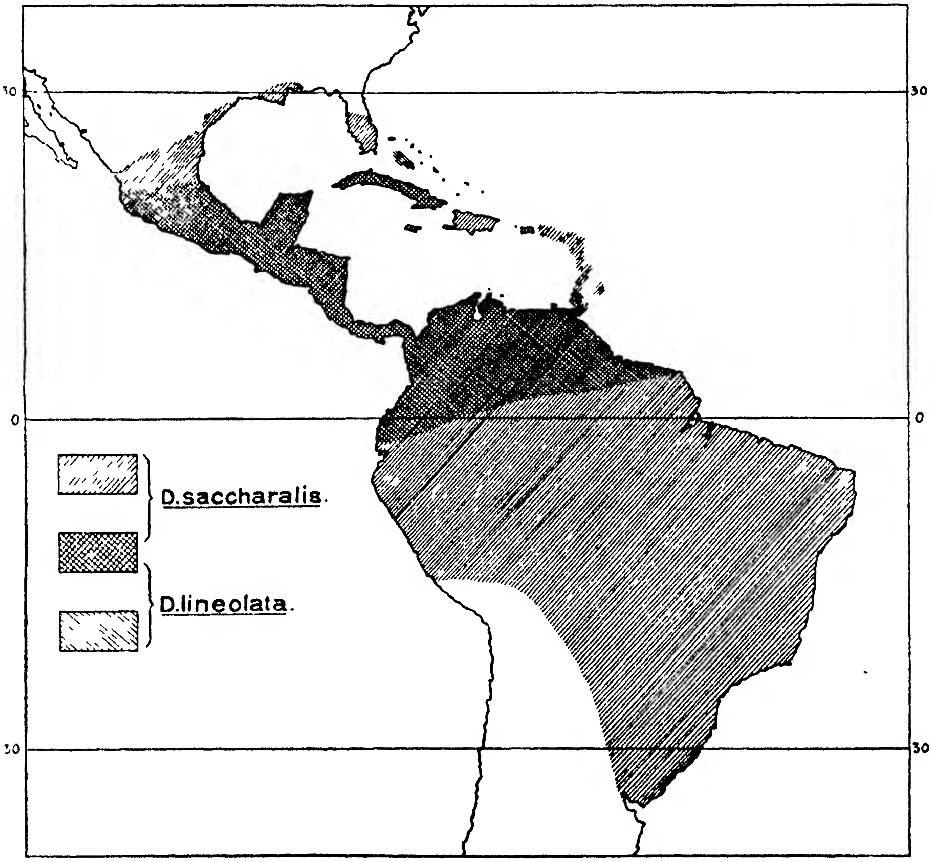

Fig. 1. The geographical range of the two most widely distributed American species of *Diatraea*.

and Jujuy, under almost precisely similar conditions, it is the predominant species, often to the exclusion of *saccharalis*, the only species at present known in Tucumán. Yet *D. dyari* occurs elsewhere in the littoral part of Argentina in abundance, under conditions very different from those of its principal habitat in the North.

Other instances of such peculiarities in distribution might be mentioned, based either on the writer's own experience in the field, or on records in literature, but a consideration of all of them leads to the conclusion that more fundamental research is needed, under strictly controlled conditions in the field and laboratory.

Taxonomic Method.

In the course of the present work all published statements concerning the species seen by the writer have been verified or corrected. In order to determine the external characters and to gain some idea of the limits within which they may vary in each species, the detailed examination of each specimen was, with few exceptions, resorted to. Since Dyar & Heinrich discovered that in this group there are certain species that are (they state) indistinguishable except on the characters of the genitalia, these organs have been dissected and examined from representative specimens of each series from each locality; altogether about 400 such dissections have been made.

With regard to the variations within each species, no details are presented here unless they are of a striking nature or of outstanding interest, but they have been

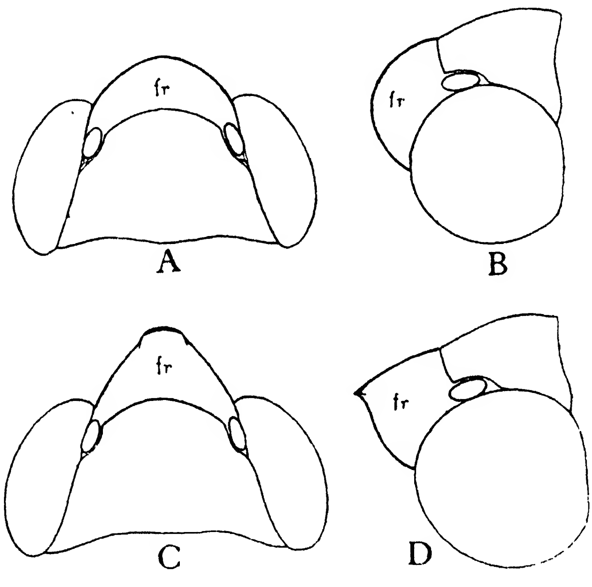

Fig. 2. Outlines of head of *Diatraea* (diagrammatic), showing extreme types of frontal structure: A, B, *Diatraea saccharalis*, from above and from side; C, D, *D. lineolata*.
(*Note*.—The thickened parts (fr) correspond to the outlines of the frons shown in figs. 3 and 4.)

taken into account in the compilation of the keys. It may be stated that the majority of the American species here considered are remarkably constant in general form and coloration, but there are a few noticeable exceptions in which this constancy is conspicuously lacking; these are discussed in the text. With regard to size, there is a great variation among the different species, the smallest measuring 14 mm. and the largest nearly 50 mm. in expanse, and to some extent within each species; dwarfed specimens are not infrequently met with, particularly in *D. saccharalis*, *D. lineolata* and *D. dyari*. The principal morphological characters, with notes upon their significance in the present discussion of *Diatraea*, are as follows:—

Frons (figs. 2, 3, 4).—The value of the frons was appreciated by Dyar & Heinrich, and in their paper these authors describe the frontal structure of nearly all the species mentioned by them; their observations, as applied to the genus *Diatraea* as a whole, are summarised in the following words: " Front either flat and smooth,

bulging, tuberculate or strongly cone-shaped."* While the form of the frons is a most useful character, it is not an infallible guide to specific identity ; in the majority of the species it is constant, but in one or two cases there is a marked tendency to dimorphism or polymorphism. This variation has been taken into account in the keys, and is discussed where necessary under each of the species concerned.

Antennae.—Referring to *Diatraea*, Dyar & Heinrich state : " Antennae somewhat thickened and minutely pubescent in the male, filiform in the female ; " they remark that their new genus *Trinidadia* differs from *Diatraea*, not only in venation, but in that the antennae of the male are pectinate. The writer has seen the male of

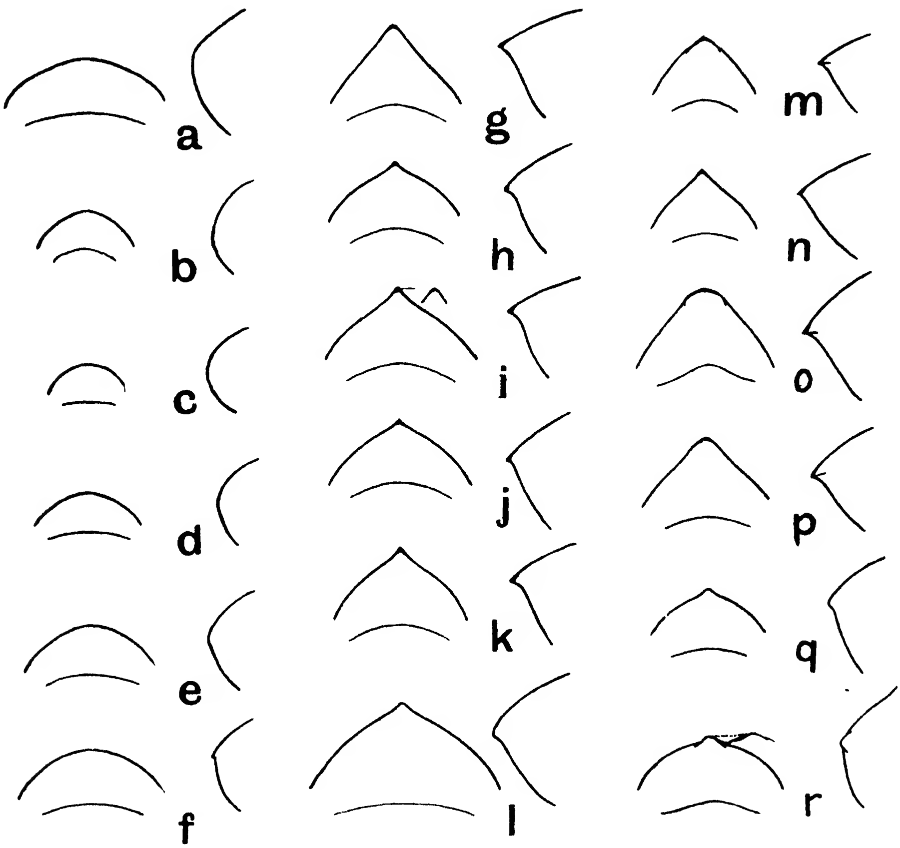

Fig. 3. Outlines of frons of *Diatraea* (diagrammatic)—for explanation, see text. (*Note.*—The outlines correspond to the thickened parts (fr) of the head shown in fig. 2.)

minimifacta, the genotype of *Trinidadia*, and finds the antennae to be of the same form as those of *incertella*, sp. n., the venation of which is intermediate between the two genera. It seems doubtful whether the type of male antenna, *i.e.*, pectinate or simple, can alone be used for a generic separation of species.

* I have not seen in *Diatraea* a frons which could correctly be described as " flat," though in the smooth rounded forms the convexity may be only slight (figs. 2, A ; 3, a–f). A " flat " frons is present in *Xanthopherne heinrichi*, sp. n. (fig. 4, l).

Since the term " tubercle " has other applications in insect anatomy, I have not employed it in this connection ; the apex of the frons does not bear a separate structure, therefore I have substituted the expressions " point " and " pointed " for " tubercle " and " tuberculate," respectively, when describing this sclerite.—H. E. B.

Proboscis.—Hampson stated (1895) " Proboscis absent," but Fernald, writing at about the same time (January 1896), said " Tongue rudimentary." Actually, a small but well-developed proboscis is present in both sexes of all the species of *Diatraea* and *Xanthopherne* seen by the writer.

Palpi.—These organs have been adequately described by previous authors. Dyar & Heinrich noted the comparatively short maxillary palpi of certain species which agree in venation with *Diatraea*, and erected their genus *Xanthopherne* accordingly.

Legs.—The fore legs and middle legs call for no comment ; neither do the hind legs of the females. In the male sex, however, the posterior tibia of nearly all the species of *Diatraea* is " hairy," *i.e.*, provided with numerous long hair-like scales on its inner margin, and in four species these scales are gathered together to form

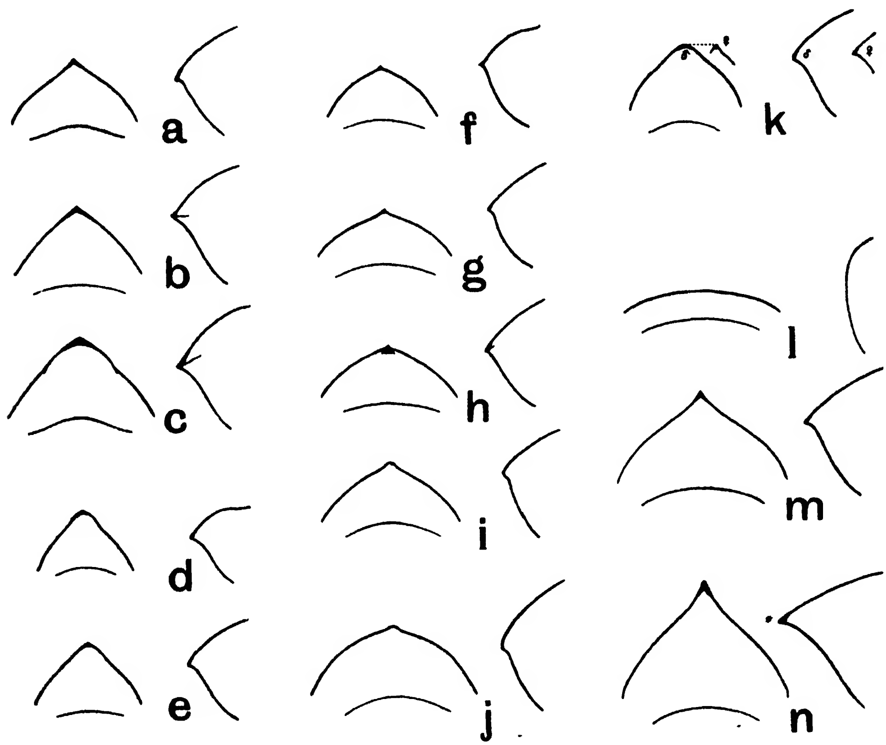

Fig. 4. Outlines of frons of *Diatraea* and *Xanthopherne* (diagrammatic)—for explanation, see text.

a large conspicuous tuft. This character was noted by Zeller in 1872, but was not referred to again until 1911, when Dyar mentions it in connection with certain species he described at that time. The presence of this tuft does not seem to be correlated with any structural change in the tibia itself, nor with other external characters, though it may be noted in passing that all four species of *Diatraea* in which it has been found belong to that limited section of the genus in which the male genitalia have a large knob-like projection from the base of the harpe, and with lateral lobes to the tegumen ; there are other species with this type of genitalia, but without the large tuft of hairs on the hind tibia. Among the three species of *Xanthopherne*

known to the writer, one is without this tuft of hair-like scales, but two species have it present, one to a much greater degree than the other ; in this case no correlation can be noted with the male genitalia.

Venation.—The venation of *Diatraea* is defined on p. 11, and is remarkably constant. The two variable features, however, call for discussion here.

(A). *Veins* 8+9 *and* 10 *in the fore wing.* Dyar & Heinrich recognised as *Diatraea* only those species in which vein 10 was separate from 8+9, being free at its base, from the cell (fig. 5, A). (One species, *minimifacta*, Dyar, was separated from *Diatraea* to form the new genus, *Trinidadia*, on account of the stalking of veins 4 and 5 in both wings, which feature is discussed below.) Those species in which vein

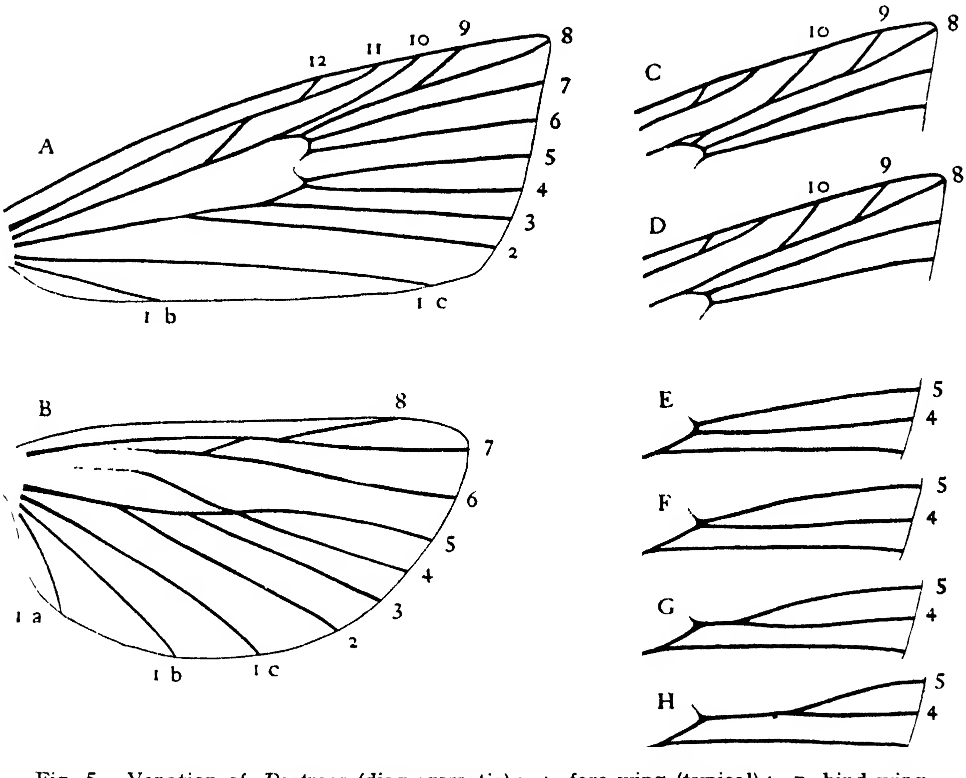

Fig. 5. Venation of *Diatraea* (diagrammatic) : A, fore wing (typical) ; B, hind wing (typical) ; C, part of fore wing showing unusual stalking of vein 10 with 8+9, vein 10 being free, from the cell, at the base ; D, the same, but with vein 10 stalked with 8+9 from the base ; E–H, part of fore wing showing transition from vein 4 being separate from vein 5 at base to the stalking of these veins for half their length.

10 is not free at its base, but is stalked with 8+9 for some distance (fig. 5, D), formed the genus *Iesta*, Dyar, which is recognised as valid by Dyar & Heinrich. In the course of the present investigations, however, it has been discovered that the stalking of vein 10 with 8+9 may occur in species in which this vein is normally free. Had this abnormality, as it must be considered, been limited to a single specimen, it might have been reckoned as a freak and nothing more. but as a matter of fact it has been found in several specimens in three distinct and widely separated species of *Diatraea*, including the genotype, *D. saccharalis*. In view of this, it now seems hardly possible to continue the recognition of *Iesta* as a separate genus, particularly as no other characters are available to differentiate it from *Diatraea*. It is of great

interest to note, in this connection, that a specimen of *D. canella* has been seen in which the venation appears to be intermediate between the two types, vein 10 being free, from the cell, at its base, then united with 8+9 for some distance, becoming free again near the apex (fig. 5, C). No examples of " *lesta* " (in the sense of Dyar & Heinrich) have been seen with the " *Diatraea* " type of venation, though the writer believes that such would be found if a sufficient number were examined. The abnormality in *Diatraea* has only been noted in the female sex, among the following :—

D. saccharalis, Fabr.—In 2 ♀♀ among 126 ♂♂ and 295 ♀♀ examined.*
D. luteella, sp. n.—In 1 ♀ among 1 ♂ and 2 ♀♀.
D. entreriana, sp. n.—In 3 ♀♀ among 5 ♂♂ and 54 ♀♀.

(B). *Veins* 4 *and* 5 *in both wings*. In *Diatraea*, as here recognised, both wings have veins 4 and 5 normally separate at their bases (fig. 5, E), but in certain species, e.g., *tabernella*, *dyari*, etc., specimens are commonly met with in which these veins are definitely united at their bases (fig. 5, F), or even stalked together for a short distance. The extreme stalking of these veins in both wings is seen in *D. minimifacta* (fig. 5, H), and this feature (together with the pectination of the male antenna) caused Dyar & Heinrich to erect a separate genus, *Trinidadia*, for this species. In *D. obliqualis*, veins 4 and 5 are stalked together in both wings, but to a lesser extent (fig. 5, G). In two species closely related to *obliqualis*, viz., *brunnescens*, sp. n., and *incertella*, sp. n., one sees a transition between the two forms of venation. *D. obliqualis* is known by the unique type only, so that unfortunately we cannot tell whether its venation is constant, but by description this species would be referable to *Trinidadia* according to Dyar & Heinrich's key. The other species mentioned (*brunnescens* and *incertella*) are obviously congeneric with *obliqualis*, but by venation belong to *Diatraea*, so that we have no alternative but to merge *Trinidadia* into the latter genus.

Genitalia.—The writer recommends that the genitalia be examined wherever there is an element of doubt as to the identity of a specimen. These organs have now been figured for nearly all of the known sexes of all the American species, the majority of those not illustrated by Dyar & Heinrich being in the present paper ; in certain cases where former figures or descriptions are inadequate, photographs are given here, particularly where it is necessary to make close comparisons between similar structures. The writer has not described the genitalia, since the excellent photographs prepared by Mr. Tams are a sure means of identification, but comparative notes are given in certain cases. The nomenclature is that proposed by Busck & Heinrich (Proc. Ent. Soc. Wash., xxiii, 1921, pp. 145–152, pls. xii–xiii).

For the examination of the female genitalia dissection of the abdominal segments concerned is unavoidable, and the final cleared preparations must be mounted so as to be viewed by transmitted light. The usual technique is sufficient, but the writer has found that better results are obtained by immersing the cleared specimen in phenol, then in absolute alcohol, before transferring to clove oil. The males of the smaller forms require similar dissection and treatment, but for the larger species, particularly where determinations can be based upon the shape of the lateral lobes of the tegumen, it is often quite sufficient to draw out the genitalia from the last segment and brush away the scales ; a few drops of wood-naphtha greatly facilitate this operation.

Abdominal tufts of the male.—Dyar & Heinrich refer to and figure certain tufts of hairs present on the second abdominal segment of the males of some species of

* The two abnormal females were reared from the same batch of eggs by Mr. Urich in Trinidad. The female parent is normal, the entire progeny successfully reared to maturity being as follows : three normal males and three females, one normal and two abnormal. Rearings from known abnormal parents would be most interesting.

Diatraea. For several reasons, but principally to avoid unnecessary mutilation of valuable specimens, the writer has not touched upon this feature in the present work. The function of these tufts appears to be unknown.

Colours.—The nomenclature employed in the text is, so far as possible, in accordance with Ridgeway's "Color Standards and Color Nomenclature," 1912 edition. The qualification is necessary since the general colouring of these moths is often a subtle blending of different shades of buff, yellowish, greyish or brownish, on a lighter ground, and actual differentiation according to Ridgeway's plates is sometimes most difficult. In the keys a conventional interpretation of the colours is used, since Ridgeway's book may not always be available for the student in the field, for whom the keys are primarily intended.

References.—Every precaution has been taken to ensure accuracy, and no papers are quoted, or mentioned, which have not been seen in the original. The writer believes that n contributions of any consequence have been overlooked by him in the course of this investigation, and that all the pertinent literature has been studied. References to the non-systematic aspects of the different species are not included with those dealing with the synonymy.

Types.—With the exception of those in the United States National Museum (species of Dyar, Schaus, and Dyar & Heinrich), all extant types (species of Walker, Zeller, Grote and Hampson) have been examined personally by the writer.

Abbreviations.—The following are employed in the text :—

B.M.—British Museum (Natural History).

I.I.E.—Imperial Institute of Entomology.

T.M.—Tring Museum.

O.M.—Museum of the Hope Department of Zoology, Oxford University.

U.S.N.M.—United States National Museum.

Z.M.U.B.—Zoologisches Museum der Universität, Berlin.

Genus DIATRAEA, Guild.

Diatraea, Guilding, Trans. Soc. Encour. Arts., etc., xlvi, 1828, p. 148 ; Zeller, Hor. Soc. Ent. Ross., xvi, 1881, p. 161 ; Fernald, Ent. Amer., iv, 1888, p. 119 ; Möschler, Die Lepidopterenfauna v. Portorico, 1890, p. 322 ; Hampson, Proc. Zool. Soc. Lond., 1895, p. 953 ; Fernald, Crambidae of N. Amer., Mass. Agr. Coll., spec. bull., Jan. 1896, p. 73 ; Druce, Biol. Centr.-Amer., Ins., Lep.-Het., ii, 1881–1900, p. 295 ; Dyar, Bull. U.S. Nat. Mus., lii, 1902, p. 411 ; Proc. Ent. Soc. Wash., xi, 1909, p. 29 ; Ent. News, xxii, 1911, p. 199 ; Barnes & McDunnough, Check List Lep. Bor. Amer., 1917, p. 141 ; Forbes, J. N.Y. Ent. Soc., xxviii, 1920, p. 224 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 6. (Type : *Phalaena saccharalis*, Fabr.)

Diaraetria (*sic*), Guilding, Grote, New Check List N. Amer. Moths, 1882, p. 56.

Diatraerupa, Schaus, Ann. Mag. N.H., xi (8), 1913, p. 240. (Type : *Diatraerupa guapilella*, Schs.)

Iesta, Dyar, Proc. Ent. Soc. Wash., xi, 1909, p. 29 ; Forbes, J. N.Y. Ent. Soc., xxviii, 1920, p. 224 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 4. (Type : *Iesta lisetta*, Dyar.)

Trinidadia, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 5. (Type : *Diatraea minimifacta*, Dyar.)

The definition of *Diatraea* given by Dyar & Heinrich is accepted here, but with the description of the venation modified as follows :—Fore wing with vein 3 before angle of cell ; 4 and 5 separate or united at origin or stalked together for some distance

(fig. 5, E–H); 6 below apex of cell; 7 at apex; 8–9 stalked, from before end of cell; 10 arising shortly basally thereof (fig. 5, A), or stalked with 8–9 (fig. 5, C–D); 11 anastomosed with 12. Hind wing with veins 4–5 from the angle of the cell, separate or united at origin or stalked together for some distance (see p. 10).

This includes *Iesta* and *Trinidadia*, both of which were regarded as valid genera by Dyar & Heinrich. It is worthy of note that in no instance has a specimen of *Diatraea* (*sens. lat.*) been seen in which veins 11 and 12 of the fore wing do not anastomose, though in several the union of these veins is very short. This anastomosis, the characteristic palpi, and the absence of ocelli are the three essential characters upon which the present conception of *Diatraea* is based, together with the type of genitalia described by Dyar & Heinrich, so far as the American species only are concerned.

Forty-eight species are here considered, of which ten are new to science.*

Key to the Species of Diatraea.

(*Note.*—In this key the colour nomenclature is conventional, but in the text that follows, it is according to R. Ridgeway's "Color Standards and Color Nomenclature," 1912.)

1. Fore wing with one or two oblique lines, or rows of dots on the veins beyond the cell, always present but sometimes very indistinct, often represented as slight thickenings of the vein linings ... ... 2.
   Fore wing without oblique lines or rows of dots on the veins; the pattern formed by lines of scales, darker than the ground-colour, on and between the veins ... ... 42.
2. Fore wing with ground-colour whitish or at most tinged with buff or pale yellowish; small species, not exceeding 20 mm. expanse ... ... 3.
   Fore wing buff, straw-yellow, brownish or greyish tinged with pinkish; small to large species, those less than 20 mm. expanse never whitish ... ... 5.
3. Fore wing with vein 10 free, from the cell (fig. 5, A) (Argentina) 1. *lentistrialis*, Hamps.
   Fore wing with vein 10 stalked with 8+9 for some distance (fig. 5, D)... 4.
4. Fore wing tinged with pale yellowish straw-colour (U.S.A. to Panama) 2. *lisetta*, Dyar.
   Fore wing whitish, sometimes tinged with buff, but without any yellowish tint (Argentina) ... ... 3. *argentina*, sp. n.
5. Frons convex, sometimes bulging, without a point or protuberance at the apex (figs. 2, A–B; 3, *a–f*) ... ... 6.
   Frons either slightly convex with a point or a rounded protuberance at the apex, or triangularly or conically produced, with or without a point at the apex (figs. 2, C–D; 3, *g–r*; 4, *a–c*) ... ... 14.
6. Fore wing with vein 10 normally stalked with 8+9 for some distance (fig. 5, D); a small blackish triangular mark below costa at apex; a bright orange-brown area extending beyond apex of cell (Mexico, Guatemala) 4. *morobe*, Dyar.
   Fore wing with vein 10 normally free, from the cell (fig. 5, A); without a triangular mark below costa at apex; without a bright orange-brown area beyond apex of cell ... ... 7.

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* Seven other species are known to the writer in the collections of the British Museum and Tring Museum. They are not described, however, as each is represented by a unique female, generally in poor condition.

7\. Hind wing with a dark-shaded submarginal band ... ... 8.
Hind wing without a dark-shaded submarginal band ... ... 9.

8\. Hind wing lighter than fore wing (South-eastern U.S.A.) 5. *crambidoides*, Grt.
Hind wing as dark as fore wing (Guatemala) ... 6. *postlineella*, Schs.

9\. Fore wing with veins 4 and 5 stalked together for some distance (fig. 5, G–H); small species, not exceeding 19 mm. expanse (Venezuela, Trinidad, Guianas) 7. *minimifacta*, Dyar.
Fore wing with veins 4 and 5 not stalked, or at most just united at their bases (fig. 5, E–F); small to large species ... ... 10.

10\. Fore wing light buff; the veins, when lined, infuscate; oblique lines faint, dotted (Argentina) ... ... 8. *dyari*, Box.
Fore wing yellowish straw-colour or brownish, the veins, when lined, brownish; oblique lines generally contrasting ... ... 11.

11\. Small species, less than 19 mm. expanse. Fore wing with the " veins strongly lined in brown, but narrowly and without contrast " (Panama) 9. *gaga*, Dyar.
Medium to large species, more than 20 mm. expanse. Fore wing with the veins less strongly lined in brown, but often contrasting ... ... 12.

12\. Fore wing with both oblique lines resolved into separate dots on the veins, the dots on the first line sometimes elongated (South-eastern U.S.A.) 5. *crambidoides*, Grt.
Fore wing with the first oblique line almost continuous and irregularly wavy; second line resolved into separate dots or short streaks on the veins ... 13.

13\. Female very large; expanse 44 mm. (Mexico) ... 10. *instructella*, Dyar.
Female smaller; expanse not exceeding 42 mm. (U.S.A., Central and South America, West Indies) ... ... 11. *saccharalis*, Fabr.

14\. Hind wing light brownish to dark brownish ... ... 15.
Hind wing whitish, or at most slightly tinged with buff ... ... 22.

15\. Males ... ... 16.
Females ... ... 20.

16\. Posterior tibia with a large tuft of brownish to blackish hair-like scales 17.
Posterior tibia without a tuft of hair-like scales ... ... 18.

17\. Frons triangularly produced, almost as long as broad, the apex pointed (fig. 3, *g*) (Central America, Colombia) ... ... 12. *tabernella*, Dyar.
Frons convex, about one-half as long as broad, the apex sharply pointed (fig. 3, *h*) (Guianas, ?Argentina) ... ... 13. *pedibarbata*, Dyar.

18\. Fore wing with the veins rather strongly contrasted in lines of brownish scales, with " broad intervenular streaks " (Central America) 16. *fuscella*, Schs.
Fore wing with the veins not strongly contrasting, without " broad intervenular streaks " ... ... 19.

19\. Fore wing light brownish straw-colour; oblique rows of dots well defined and contrasting (Mexico)... ... ... 17. *magnifactella*, Dyar.
Fore wing dark brownish; oblique rows of dots not well defined the first forming a dark-shaded patch below the cell (Colombia) 15. *indigenella*, Dyar & Heinr.

20\. Fore wing with the veins rather strongly contrasting in lines of brownish scales; interneural lines distinct; hind wing lighter than fore wing (Central America) ... ... 16. *fuscella*, Schs.
Fore wing with the veins only slightly contrasting; interneural lines subordinated to the ground-colour; hind wing almost as dark as fore wing 21.

21. Both wings buff or light brownish, sometimes yellowish straw-colour ; frons, seen laterally, with the apex bluntly rounded (fig. 3, *l*) (Mexico) ... 17. *magnifactella*, Dyar.
Both wings rather dark brownish, fore wing strongly tinged with ochraceous ; frons, seen laterally, with the apex sharply pointed (fig. 3, *j*) (Colombia) ... 15. *indigenella*, Dyar & Heinr.

22. Fore wing with the inner angle broadly rounded, so that the inner margin is practically continuous with the outer margin ; small brownish species, less than 23 mm. expanse ... ... 23.
Fore wing with the inner angle not broadly rounded ; medium to large species, expanse exceeding 23 mm. ... ... 24.

23. Fore wing with veins 4 and 5 stalked together for some distance (fig. 5, G) (Argentina) ... ... 18. *obliqualis*, Hamps.
Fore wing with veins 4 and 5 not stalked together, or at most just united at their bases (fig. 5, E–F)
Venezuela ... ... 19. *brunnescens*, sp. n.
Rio de Janeiro ... ... 20. *incertella*, sp. n.

24. Fore wing with the second oblique line shaded or continuous, formed of short streaks on and between the veins ; if second line is denticulate, fore wing with a clear yellow shade at tornus, without a dark shade on inner margin 25.
Fore wing with the second line resolved into distinct separate dots on the veins, or denticulate (fore wing without a yellow shade at tornus ; a dark shade on inner margin) ... ... 29.

25. Fore wing with discocellular and terminal interneural dots present ... 26.
Fore wing with discocellular and terminal dots absent (French Guiana) ... 21. *umbrialis*, Schs.

26. Fore wing with first oblique line from a dark triangular shade at apex, which sometimes extends downwards as far as apex of cell ; tornus concolorous with rest of wing ... ... 27.
Fore wing without a dark triangular shade at apex ; a clear yellow area at tornus (French Guiana, Amazons) ... ... 22. *maronialis*, Schs.

27. Fore wing with the oblique lines and the dark apical shade brownish, the latter extending from apex of cell to apex of wing and bordered with orange-brown (S. Brazil, Argentina) ... ... 23. *continens*, Dyar.
Fore wing with the oblique lines and the dark apical shade fuscous blackish, the latter limited to an oblique triangular area patch at apex... ... 28.

28.* Fore wing with the first oblique line continuous from apex to inner margin, not deeply bowed around and below the cell ; hind wing with distinct fuscous terminal interneural marks on outer margin below apex (in both sexes) (Grenada, Trinidad, Brazil, Bolivia, Peru) ... 24. *bellifactella*, Dyar.
Fore wing with the first oblique line rather deeply bowed around and below the cell ; hind wing without fuscous terminal marks on outer margin (Ecuador) ... ... 25. *luteella*, sp. n.

29. Fore wing straw-yellow, buff, light or dark brownish, sometimes suffused, without any pinkish tinge, not irrorated with scattered fuscous-tipped scales 30.
Fore wing whitish, buff, greyish, often tinged with pinkish, irrorated with numerous scattered fuscous-tipped scales ... ... 38.

* The females of *bellifactella* and *luteella* have the oblique lines very faint and indistinct, though they show as short streaks on the veins of a colour slightly darker than the vein linings the genitalia, however, should be used for separating the females of these two species.

30. Fore wing greyish brown (seen under magnification, the individual scales are light buff tipped with brownish, giving a characteristic suffused appearance); oblique lines dotted, indistinct; veins infuscate (Venezuela, French Guiana) 26. *suffusella*, sp. n.
Fore wing straw-yellow, buff, or brownish, not suffused; oblique lines distinct; veins, when lined, brownish ... ... 31.

31. Males ... ... 32.
Females ... ... 35.

32. Posterior tibia without a tuft of hair-like scales (Central America) 14. *guatemalella*, Schs.
Posterior tibia with a large tuft of hair-like scales ... ... 33.

33. Tuft of hair-like scales on posterior tibia, whitish (Guiana, Brazil, Peru, Ecuador) ... ... 27. *albicrinella*, sp. n.
Tuft of hair-like scales on posterior tibia, buff, brownish or fuscous ... 34.

34. Frons broadly convex, twice as broad as long, with a sharp point at the apex (fig. 3, *h*) (Guianas, Argentina) ... ... 13. *pedibarbata*, Dyar.
Frons triangularly produced, almost as long as broad, apex pointed (fig. 3, *g*) (Central America, Colombia) ... ... 12. *tabernella*, Dyar.

35. Fore wing with a wide area on inner margin darker than rest of wing; frons convex, with a small blunt protuberance at apex (fig. 3, *r*) (British Guiana, Brazil, Peru, Ecuador) ... ... 27. *albicrinella*, sp. n.
Fore wing with inner margin concolorous with rest of wing; frons convex or triangularly produced, with a sharp point at apex (fig. 3, *g*, *h*, *i*) ... 36.

36. Fore wing with the first oblique line terminating just below the cell in an elongate fuscous patch (Central America) ... 14. *guatemalella*, Schs.
Fore wing with the first oblique line continuing to inner margin near base, not forming a dark patch below cell ... ... 37.

37. Frons broadly convex, twice as broad as long; a sharp point at the apex (fig. 3, *h*) (Guianas, Argentina) ... ... 13. *pedibarbata*, Dyar.
Frons triangularly produced, almost as long as broad; apex pointed (fig. 3, *g*) (Central America, Colombia) ... ... 12. *tabernella*, Dyar.

38. Fore wing rather long and narrow; general aspect crambiform ... ... 39.
Fore wing rather broad; general aspect not crambiform ... ... 40.

39. Fore wing whitish to greyish, tinged with pinkish; oblique lines very faint, sometimes almost obsolete, always resolved into separate dots on the veins; a whitish streak from cell to outer margin between veins 5 and 6 (French Guiana, Brazil) ... ... 35. *cayenella*, Dyar & Heinr.
Fore wing light to dark brownish, somewhat tinged with pinkish; oblique lines distinct, the first resolved into short streaks rather than dots on the veins; streak from cell to outer margin same as ground-colour, not whitish (S. Brazil)... ... ... 28. *amnemonella*, Dyar.
29. *castrensis*, Dyar & Heinr.

40. Fore wing light buff or brownish, without any pinkish tinge (Brazil, Argentina) 31. *amazonica*, sp. n.
For wing light or dark greyish or light buff, distinctly tinged with pinkish 41.

41. Fore wing with discocellular and terminal interneural dots very distinct, forming part of the wing pattern (West Indies, Venezuela, Guianas) 30. *canella*, Hamps.
Fore wing with discocellular and terminal interneural dots small, subordinated to the wing-pattern (Bolivia) ... ... 32. *rufescens*, sp. n.

42. Fore wing whitish to greyish, tinged with pinkish or sometimes with brownish, irrorated with numerous fuscous-tipped scales; general aspect crambiform 43.
Fore wing light buff, yellowish, yellowish tinged with salmon-pink, light or dark brownish, not irrorated with fuscous-tipped scales; general aspect (except in *flavipennella*) not crambiform 44

43. Fore wing whitish or light buff, without any pinkish tinge, sometimes tinged with straw-colour or light brownish on outer margin; rather small species, seldom exceeding 25 mm. expanse (Argentina) ... ... 36. ***entreriana***, sp. n.
Fore wing whitish or greyish, tinged with pinkish; outer margin never darker than rest of wing; larger, exceeding 25 mm. expanse—
(Guianas, S. Brazil)... ... 33. ***anathericola***, Dyar & Heinr.
(S. Brazil) ... ... 34. ***strigipennella***, Dyar.
(Guianas, S. Brazil)... ... ? 35. ***cayenella***, Dyar & Heinr.

44. Frons convex, sometimes bulging, the apex smooth and rounded, without a point or protuberance (fig. 3, *d–f*) ... ... 45.
Frons either slightly convex, with a point or a rounded protuberance at apex, or triangularly or conically produced, with or without a point at apex (figs. 2, C, D; 4, *d–k*) ... ... 51.

45. Fore wing with vein 10 stalked with 8+9 for some distance (fig. 5, D) (Costa Rica) ... ... 37. ***guapilella***, Schs.
Fore wing with vein 10 free, from the cell (fig. 5, A) ... ... 46.

46. Fore wing with the veins and interneural lines barely visible against the light ground-colour, the wing appearing almost uniformly pale yellowish or very light buff (South-western U.S.A., Mexico) ... 44. ***grandiosella***, Dyar.
Fore wing with the veins and interneural lines contrasting, often strongly, against the ground-colour, which may be whitish, yellowish, buff, or warm brownish ... ... 47.

47. Fore wing rather broad; the veins and interneural lines well defined in ochraceous or warm brownish, but not sharply contrasting, on a whitish ground-colour (Mexico) ... ... 44. ***grandiosella***, Dyar.
Fore wing rather narrow; the veins and interneural lines well defined and rather sharply contrasting against the ground-colour, which may be whitish, yellowish, buff, or warm brownish ... ... 48.

48. Small species, less than 23 mm. expanse; fore wing with ground-colour whitish; the veins and interneural lines strongly contrasting in chocolate-brown (Southern U.S.A.) ... ... 38. ***venosalis***, Dyar.
Medium to large species, more than 23 mm. expanse; fore wing with the ground-colour buff, yellowish, straw-colour or warm brownish; the veins and interneural lines either slightly contrasting, or strongly contrasting in different shades of ochraceous to brownish (not chocolate-brown) ... ... 49.

49. Fore wing with the costa and outer margin forming a rather acute angle; ground-colour pale yellowish or very light buff; a light streak from cell to outer margin between veins 5 and 6; general aspect crambiform (Southern Brazil) 42. ***flavipennella***, sp. n.
Fore wing with the angle formed by costa and outer margin less acute; ground-colour dark buff to warm brownish; general aspect not crambiform ... 50.

50. Fore wing "dull dark wood-brown, the veins distinctly darker . . . not contrasted" (Southern U.S.A., Central America) 39. ***evanescens***, Dyar.
Fore wing with ground-colour buff to light brownish, the veins and interneural lines rather sharply and narrowly contrasted in different shades of brownish (S. Brazil, Paraguay, ?Argentina) ... ... 40. ***angustella***, Dyar.

51. Fore wing yellowish straw-colour, strongly tinged with brownish on inner margin, especially at base; the veins very strongly contrasting in warm brownish (Central America, Colombia) ... 45. *schausella*, Dyar & Heinr.
Fore wing with the inner margin concolorous with rest of wing; the veins either strongly contrasting but with interneural lines also forming part of the pattern, or veins and interneural lines not contrasted at all, leaving the wing almost uniformly light buff or pale yellowish ... ... 52.
52. Frons either gently convex with a sharp point at the apex, or strongly convex with a rounded protuberance at the apex (fig. 4, *g–j*) ... ... 53.
Frons triangularly or conically produced with the apex rather abruptly truncate (fig. 2, C–D) ... ... 57.
53. Fore wing with the veins and interneural lines barely visible against the light ground-colour, the wing appearing almost uniformly pale yellowish or very light buff; frons convex, with a slight rounded protuberance at apex (fig. 4, *j*) (South-western U.S.A., Mexico) ... ... 44. *grandiosella*, Dyar.
Fore wing with the veins and interneural lines contrasting against the ground-colour, forming a distinct pattern; frons as above or with a sharp point at apex (fig. 4, *g–i*) ... ... 54.
54. Fore wing rather broad, the apex rounded; the veins and interneural lines well defined in ochraceous or warm brownish, but not sharply contrasting, on a whitish ground-colour (Mexico) ... ... 44. *grandiosella*, Dyar.
Fore wing rather narrow, the apex pointed; the veins and interneural lines well defined and rather sharply contrasting against the ground-colour, which may be yellowish, straw-colour, salmon-pink, buff or warm brownish 55.
55. Head, thorax and fore wing strongly tinged with salmon-pink; male with a large tuft of brownish to blackish hair-like scales on posterior tibia (Panama, Colombia, Venezuela) ... ... 43. *busckella*, Dyar & Heinr.
Head, thorax and fore wing yellowish, buff or warm brownish, without any salmon-pink tinge; male without a tuft of hair-like scales on posterior tibia 56.
56. Frons convex, with a sharp point at the apex (fig. 4, *h*); fore wing with discocellular and terminal interneural dots distinct, blackish (Venezuela, Trinidad, Guianas, Brazil, ?Bolivia, ?Argentina) 41. *impersonatella*, Walk.
Frons convex or bulging, with a rounded protuberance, sometimes resembling a point, at the apex (fig. 4, *g*); fore wing with discocellular and terminal interneural dots small, faint (Paraguay, ?Argentina) 40. *angustella*, Dyar.
57. Fore wing with a distinct, strongly contrasted, whitish streak through cell to outer margin between veins 5 and 6; "hind wing a little dusky apically" (São Paulo) ... ... 46. *pallidostricta*, Dyar.
Fore wing without a strongly contrasting whitish streak through cell and beyond, at most a streak of the light buff or pale yellowish ground-colour; hind wing uniformly whitish ... ... 58.
58. Fore wing with discocellular and terminal interneural dots present (Mexico, Central America, West Indies, Northern S. America) 47. *lineolata*, Walk.
Fore wing with discocellular and terminal dots absent (Central Mexico)* 48. *muellerella*, Dyar & Heinr.

1. Diatraea lentistrialis, Hamps. (Pl. i, fig. 15).

Diatraea lentistrialis, Hampson, Ann. Mag. N.H. (9) iii, 1919, p. 546.

A minute whitish species with the veins and oblique lines strongly contrasted in dark brownish. The frons is smooth and convex (fig. 3, *c*).

* This character is based upon one specimen, a female, of *muellerella*, and a long series of *lineolata* of both sexes. Dyar & Heinrich state that the former is "superficially indistinguishable from *lineolata*, Walker. Separable on details of the genitalia"

This species bears a superficial resemblance to *argentina*, sp. n., from the same locality, and *lisetta*, Dyar (U.S.A., Central America), but differs from them in that vein 10 of the fore wing is free, from the cell (fig. 5, D). It is clearly a link between the forms hitherto referred to *Iesta* and those considered as *Diatraea*.

The unique male type, in the British Museum, is labelled " ARGENTINA, Gran Chaco, nr. Florenzia, x.1902 (*S. R. Wagner*)." Expanse 16 mm.

2. Diatraea lisetta, Dyar.

Iesta lisetta, Dyar, Proc. Ent. Soc. Wash., xi, 1909, p. 29 ; Ent. News, xxii, 1911, p. 204 ; Barnes & McDunnough, List. Lep. Bor. Amer., 1917, p. 141 ; Forbes, J. N.Y. Ent. Soc., xxviii, 1920, p. 224 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 4, ff. 28, 47.

Iesta cancellalis, Dyar, Proc. U.S. Nat. Mus., xlvii, 1915, no. 2050, p. 320 ; Dyar & Heinrich, *loc. cit.*

Iesta adulcia, Dyar, Proc. U.S. Nat. Mus., li, 1917, no. 2139, p. 37 ; Dyar & Heinrich, *loc. cit.*

A small, light-coloured species, closely related to *D. argentina*, sp. n. (Argentina), but with the fore wing more yellowish to ochraceous-buff than whitish. The frons is smooth and gently convex (fig. 3, *b*).

1 ♂, 4 ♀♀ (B.M.) :—MEXICO : Teapa, Tabasco (*H. H. Smith*). PANAMA : Corozal, C.Z., 26.iv.1911 (*A. Busck*).

The Mexican specimens are part of the Godman-Salvin collection, and are erroneously referred to *D. saccharalis* in the " Biologia Centrali-Americana." The example from Panama is labelled " *Iesta cancellalis*, Dyar."

This species is also known from Florida and Alabama in the U.S.A.

3. Diatraea argentina, sp. nov. (Pl. i, fig. 14 ; Pl. v, fig. 2).

Fore wing with vein 10 stalked with 8+9 (fig. 5, D).

♂. Palpus cartridge-buff above, tinged with avellaneous to wood-brown at sides and below. Antennal shaft dark brownish with sparse cartridge-buff scales. Head whitish or cartridge-buff ; a narrow avellaneous streak on vertex. Thorax cartridge-buff ; base of patagium avellaneous to wood-brown. Tergum whitish to light buff, proximal two segments warm buff. Pectus cartridge-buff, tinged with light buff. Legs the same. Venter the same, though generally lighter. Fore wing with ground-colour cartridge-buff, tinged with light buff to warm buff at base and especially along costa ; the veins lined with ochraceous-buff to cinnamon-buff scales ; similar, but rather lighter, lines of scales between the veins ; a cluster of avellaneous scales in cell at base ; a conspicuous fuscous blackish discocellular dot ; two oblique lines composed of short elongated patches of wood-brown to fuscous scales on and between the veins, the first from vein 8 at middle, in a wide curve (concavity basad) around and below the cell to vein 1c, then rather abruptly curved downwards to run into inner margin at a point one-third its length from base ; the second line an almost uniform curve parallel to the outer margin, extending from just below apex to inner margin just beyond middle, at which point it tends to broaden somewhat into a fuscous patch ; a terminal series of rather large fuscous blackish interneural dots. Hind wing whitish tinged with cartridge-buff. Underside of fore wing warm buff to avellaneous, tinged with wood-brown except on outer margin, much darker on a triangular patch at apex ; the veins slightly infuscate ; discocellular dot faint ; a terminal fuscous line thickened interneurally to form dots ; of hind wing cartridge-buff tinged with light buff, tinged with warm buff on costa and outer margin at apex. Expanse 18 mm.

♀. Similar, slightly larger, colouring generally more whitish, the markings on the fore wing much less distinct; underside of fore wing almost uniformly light buff. Expanse 18·5–20 mm.

In both sexes the frons is convex, smooth, slightly bulging, and without a point at the apex (fig. 3, *b*).

ARGENTINA: Gran Chaco, nr. Florenzia, 2 ♂♂, 2 ♀♀, x.1902 (*S. R. Wagner*).

Holotype ♂ in British Museum; paratypes in B.M. and U.S.N.M.

A small light-coloured species closely related to *lisetta*, Dyar (U.S.A., Central America), but more whitish than yellowish, and with different genitalia. By the venation, *argentina* falls naturally into *Iesta* in the generic key given by Dyar & Heinrich. *D. lentistrialis*, Hamps., from the same locality in Argentina, has a close superficial resemblance to *argentina*, but it is smaller and the oblique lines on the fore wing are more rufous than fuscous; furthermore, *lentistrialis* has vein 10 in the fore wing free from the cell.

4. Diatraea morobe, Dyar (Pl. i, figs. 18, 19).

Iesta morobe, Dyar, Proc. U.S. Nat. Mus., li, 1917, no. 2139, p. 37; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 5, f. 46.

Hitherto known only by the unique female type in the U.S. National Museum, from Teapa, Tabasco, Mexico.

Dyar & Heinrich remark that "This may prove to be a varietal form of *guapilella* with which it agrees in genitalia." The latter (*q.v.*, p. 40) is also known only in the female sex, and is separated from *morobe* by the absence of a distinct outer line on the fore wing, which is present in *morobe*. Schaus described *guapilella* from Costa Rica and created for it a new genus, *Diatraerupa*, differing from *Iesta* in having veins 4 and 5 stalked in the fore wing. Dyar & Heinrich do not recognise *Diatraerupa*, otherwise the species at present being discussed would also belong there.

The British Museum has two males from Guatemala, agreeing with the description of *morobe*, and the writer has little hesitation in accepting them as that species. The description follows:—

♂. Palpus warm buff streaked with wood-brown. Antennal shaft honey-yellow with sparse warm buff scales. Head warm buff tinged with cinnamon-buff. Thorax cinnamon-buff tinged with cinnamon. Tergum light buff, proximal two segments cinnamon-buff. Pectus light buff tinged with warm buff. Legs light buff. Venter light buff. Fore wing with ground-colour light buff strongly tinged with warm buff, irrorated with numerous scattered fuscous-tipped scales which tend to form interneural lines; the veins lined with cinnamon-buff to cinnamon scales; a conspicuous blackish discocellular dot; an irregular patch of ochraceous-tawny to Mars yellow extending from middle to slightly beyond apex of cell, tending to merge into the linings on the basal part of veins 5 to 11, much lighter (warm buff to ochraceous buff) on a small elongate area immediately surrounding the discocellular dot, this central shade merging into cinnamon-brown at its apex; a fuscous blackish (near bone-brown) triangular patch below costa at apex; an ochraceous tawny patch at inner angle below tornus; two oblique fuscous lines, the first being a continuation downwards and inwards of the dark central shade, extending from base of cell in a rather wide patch, which is sharply defined on its inner side but tends to run along the veins on its outer side, thence to vein 1c and bending to run into inner margin at a point one-third its length from base; the second line resolved into separate rounded fuscous dots on the veins, extending in a wide curve, almost parallel to the outer margin, from the triangular apical shade to the inner margin about two-thirds its length from base; a terminal series of small blackish interneural dots. Hind wing whitish tinged with cartridge-buff or cream-colour; traces of terminal

fuscous dots on outer margin below apex. Underside of fore wing Verona brown; a pinkish buff streak extending from cell to outer margin, joining a similar shade which extends the length of the latter; a similar light-coloured area on inner margin below vein 1c; discocellular dot faint, brownish; terminal dots distinct, blackish; of hind wing cream-colour slightly tinged with warm buff, especially on costa and at apex; traces of fuscous terminal dots on outer margin below apex. Expanse 24 mm.

GUATEMALA: Las Mercedes, 3,000 ft., 2 ♂♂ (*Champion*—B.M.).

The frons is smooth and gently convex (fig. 3, *b*).

These two specimens, from the Godman-Salvin collection, were erroneously referred to *D. saccharalis* in the "Biologia Centrali-Americana."

5. Diatraea crambidoides, Grt. (Pl. iii, fig. 1).

Chilo crambidoides, Grote, Canad. Ent., xii, 1880, p. 15 (*nec* Hampson, Proc. Zool. Soc. Lond., 1895, p. 953, *et auctt.*, = *D. saccharalis*, Fabricius).

Diaraetria (*sic*) *crambidoides*, Grote, New Check List N. Amer. Moths, 1882, p. 56.

Diatraea crambidoides (Grt.), Fernald, Ent. Amer., iv, 1888, p. 120 (nec *Diatraea saccharalis crambidoides*, Dyar, Ent. News, xxii, 1911, p. 200, *et auctt.*, = *D. saccharalis*, Fabr.).

Diatraea zeacolella, Dyar, Ent. News, xxii, 1911, p. 203; Barnes & McDunnough, Check List Lep. Bor. Amer., 1917, p. 141; Holloway, J. Agric. Res., vi, 1916, p. 621, ff. (larva); Heinrich, in U.S. Dept. Agr. Bull. 746, 1919, ff. (larva); Forbes, Cornell Univ. Agr. Expt. Sta. Mem. 68, 1913, p. 591; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 19, ff. 11, 59.

Diatraea tripsacicola, Dyar, Insec. Insc. Menst., ix, 1921, p. 193; Dyar & Heinrich, *loc. cit.*

The most recent discussion of the identity of *crambidoides*, Grt., is that of Dyar & Heinrich, who treat the name as a synonym of *D. saccharalis*, though they later state in the same article, when discussing *D. zeacolella*, "It is probable that *Chilo crambidoides* Grt., referred to the synonymy of *saccharalis*, is an earlier name for this species" (*i.e.*, of *zeacolella*). "*C. crambidoides* was described from Kansas, whence we have received a specimen of *zeacolella*, but we have never seen *saccharalis* from north of the Gulf coast region." The location of Grote's type was not known to these authors; it is in the British Museum, and an examination of it confirms their suspicions as to the identity of *zeacolella* with *crambidoides*.

Hampson, in 1895, considered Grote's species to be the same as *saccharalis*, and he was followed by several authors between that year and 1911, when Dyar employed the name *crambidoides* with subspecific rank for the North American "form" of *saccharalis*. The confusion in the economic literature is therefore great, and it is to be hoped that the correct synonymy given above will definitely establish the identity of the species.

Dyar stated in 1911 that "the figures published by Dr. Howard of the 'larger corn-stalk borer' (Insect Life, iv, 95, 1891)* represent *D. zeacolella*." The present writer has seen Dr. Howard's account, and is in agreement with Dyar's observation, which also applies to G. G. Ainslie's three revisions of Howard's paper (U.S. Dept. Agric., Bur. Ent. Circ. 116, 1910, pp. 1–8, ff. 1–4; Farmers' Bull. 634, 1916, pp. 1–8, ff. 1–7; and Farmers' Bull. 1025, 1925, pp. 1–12, ff. 1–8). Ainslie, in his first two papers, follows Howard in using the name *D. saccharalis* for this insect, thinking that the species he discusses was the same as the sugar-cane borer of Louisiana and elsewhere; in his third paper, Ainslie employs the name

Reprinted as Circular 16, U.S. Dept. Agric., Bur. Ent. (1891).

D. zeacolella. These papers give a very complete account of *D. crambidoides* and the damage done in the areas infested by it, which seem to be limited to the south-eastern United States " from Northern Florida to Maryland." This species must not be confused with the " South-western Corn Borer " (*D. grandiosella*, Dyar).

Corn or maize (*Zea mays*, Linn.) is undoubtedly the preferred food-plant of *crambidoides*, sugar-cane being only occasionally attacked by it. " Even where cane is grown, the insect rarely attacks it, although the closely related sugar-cane borer feeds on corn and sugar-cane indiscriminately " (Ainslie, 1925).

Technical descriptions of the larva are given by Holloway (*l.c.*) and Heinrich (*l.c.*).

Only one specimen other than the female type in the British Museum has been examined in the course of the present studies, *viz.*, a male in the Tring Museum, labelled " Titusville, S. Florida, viii.1894."

6. **Diatraea postlineella,** Schs.

Diatraea postlineella, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 138 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 20, f. 12.

Unknown to the writer. " A rather large, darkly shaded species," known only by the unique male type in the U.S. National Museum, from Quirigua, Guatemala. Expanse 27 mm.

Schaus states : " The only species of *Diatraea* I know with a distinct line on hind wing," but according to Dyar & Heinrich, a faint sub-terminal line is also present on the hind wing of the male of *crambidoides*. The genitalia, which are of peculiar form, indicate a close relationship with the latter species.

7. **Diatraea minimifacta,** Dyar.

Diatraea minimifacta, Dyar, Ent. News, xxii, 1911, p. 202.

Trinidadia minimifacta (Dyar), Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 6, ff. 29, 48.

A small, brownish species, with markings rather like those of *D. saccharalis*, but with a dark apical shade in the fore wing of the male. This form was separated from *Diatraea* by Dyar & Heinrich to form their new genus, *Trinidadia*, on account of the union of veins 4 and 5 in both wings (fig. 5, H) and the pectination of the male antennae (see pp. 7, 10).

The frons is smooth and gently convex (fig. 3, *d*), but in other respects this moth appears to be rather closely related to *obliqualis*, Hamps. (Argentina), which has somewhat similar venation and a general superficial resemblance to *minimifacta*.

Two males have been seen (T.M., O.M.) :—VENEZUELA : Caracas. TRINIDAD : Maraval, vii.1891.

Two females from Trinidad (B.M.) agree externally with the description of this species, and have the same type of frons as the above males, but the genitalia (Pl. v, fig. 5) differ from those figured for this species by Dyar & Heinrich, and more closely resemble those of *obliqualis* ; the female genitalia illustrated by Dyar & Heinrich correspond more closely with those of a female in the British Museum from Corrientes, Argentina (sp. nov. ined.,* Pl. v. fig. 8), but which cannot be *minimifacta* owing to the different frontal structure (fig. 3, *m*).

D. minimifacta is also known from St. Jean and St. Laurent, French Guiana.

* See foot-note, p. 12.

8. Diatraea dyari, Box.

Diatraea dyari, Box, Bull. Ent. Res., xxi, 1930, p. 307, pl. x, ff. 1–3.

No specimens other than the type and numerous paratypes, all from Argentina, and listed with the recently published description, have been seen.

In connection with the present studies, a careful examination has been made of the venation of all these specimens. It is noticeable that in the fore wing vein 11 generally makes but a short anastomosis with vein 12. The configuration of the bases of veins 4 and 5 is very variable, and numerous examples of both sexes have been seen in which these two veins are united and in a few instances stalked together for a short distance (fig. 5, F, G). The frons has been described, but is here illustrated (fig. 3, *a*).

D. dyari is an important pest of sugar-cane in Northern Argentina, particularly in the district around San Pedro de Jujuy, but the species obviously has other food-plants, probably maize, in the provinces of Entre Rios, Santa Fé, etc., where it also occurs, apparently in abundance. Where both crops are grown, sugar-cane is the preferred host.

9. Diatraea gaga, Dyar.

Diatraea gaga, Dyar, Proc. U.S. Nat. Mus., xlvii, 1915, no. 2050, p. 319 ; Dyar & Heinrich, *op. cit.*, lxxi, 1927, no. 2691, p. 18, f. 9.

Diatraea solipsa, Dyar, *loc. cit.* ; Dyar & Heinrich, *loc. cit.*

Unknown to the writer. " A small species resembling an *Iesta* " (expanse: ♂♂, 13–18 mm. ; ♀♀, 16–18 mm.), known from Corozal and Porto Bello, Panama.

The male genitalia suggest a close relationship with *lentistrialis*, Hamps. (Argentina), and the moth seems similar to that species, though darker, being more generally brownish than whitish.

10. Diatraea instructella, Dyar.

Diatraea instructella, Dyar, Ent. News, xxii, 1911, p. 201 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 10, f. 49.

Unknown to the writer. Known only by the unique female type in the U.S. National Museum, from Popocatepetl Park, Mexico.

Except for its abnormal size (expanse 44 mm.), the description of the type agrees externally with several distinctively marked female *saccharalis* in the British Museum, from Mexico and Guatemala, as to the identity of which there is no doubt. The genitalia of *instructella*, described and figured by Dyar & Heinrich, are rather different from those of *saccharalis*. These authors state that the female genitalia of *moorella* (= *impersonatella*) are as in *instructella*, and that those of *pedibarbata* and *continens* resemble *instructella* except for details. The genitalia of the last named three species have been seen by the writer, and each has been found to be quite distinctive. Examples of *saccharalis* have been seen in which the female genitalia approach the *instructella* type.

11. Diatraea saccharalis, Fabr.* (Pl. iii, fig. 8).

Phalaena saccharalis, Fabricius, Ent. Syst., iii (2), 1794, p. 238 ; Skrift. af Naturhist. Selsk., iii (2), 1794, p. 63, pl. vii, f. 1 (nec *Borer saccharellus*, Guenée, Annexe G, Lépid. in Maillard, Notes sur l'île de la Réunion, 1862, p. G–70).

* *Chilo comparellus*, Felder & Rogenhofer (Reise Novara, Zool., ii (2), 1875, f. 5), from Bogotá (Colombia), has been cited in the synonymy of *D. saccharalis* by Hampson and subsequent authors, who seem to have been guided by the original figure ; the type is in the Tring Museum and has been examined by the writer. It is not a *Diatraea* and may possibly belong to *Chilo* (sens. lat.).

Crambus sacchari, Fabricius, Suppl. Ent. Syst., 1798, p. 469.

Diatraea sacchari, Guilding, Trans. Soc. Encour. Arts, etc., xlvi, 1828, p. 149, 1 pl. (nec *Phalaena sacchari*, Sepp, Surinamsche Vlinders n. h. Leven geteekend, ii, 1848, p. 135, pl. 64, =*Diatraea canella*, Hamps.).

Crambus leucaniellus, Walker, List Lep. Ins. Brit. Mus., xxvii, 1863, p. 161.

Crambus lineosellus, Walker, *op. cit.*, p. 162.

Chilo obliteratellus, Zeller, Chilonid. et Crambid., 1863, p. 8; Ent. Zeit., 33, 1872, p. 465 (part); Hor. Soc. Ent. Ross., xiii, 1877, p. 13 (Exot. Microlep., p. 11) (part); Walker, List. Lep. Ins. Brit. Mus., xxx, 1864, add. p. 966; Felder & Rogenhofer, Reise Nov., Zool., ii (2), 1875, t. cxxxvii, f. 24.

Diatraea obliteratella, Zeller, Hor. Soc. Ent. Ross., xvi, 1881, p. 163, t. xi, f. 5 *a*, ♂ (not f. 5 *b*, ♀, = *D. tabernella*, Dyar) (part); Möschler, Lepid. v. Portorico, 1890, p. 322.

Diaraetria (sic) *saccharalis* (Fabr.), Grote, New Check List N. Amer. Moths, 1882, p. 56.

Diatraea saccharalis (Fabr.), Fernald, Ent. Amer., iv, 1888, p. 120; Hampson, Ann. Mag. N.H., (6) xvi, 1895, p. 348; Proc. Zool. Soc. Lond., 1895, p. 953, f. 36; Fernald, Crambidae of N. Amer., Mass. Agr. Coll. (Spec. Bull.), Jan. 1896, p. 74, Pl. C, figs. 10–12, pl. i, f. 8; Druce, Biol. Centr.-Amer., Ins. Lep.-Het., ii (1881–1900), p. 296, pl. lxiv, f. 29; Dyar, Bull. U.S. Nat. Mus., 52, 1902, p. 411; Proc. Ent. Soc. Wash., xi, 1909, p. 29; Ent. News, xxii, 1911, p. 199; Barnes & McDunnough, Check List Lep. Bor. Amer., 1917, p. 141; Forbes, J. N.Y. Ent. Soc., xxviii, 1920, p. 224; Heinrich, in U.S. Dept. Agr., Tech. Bull. 41, 1928, ff.; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 11, ff. 1, 2, 54.

Diatraea saccharalis saccharalis (Fabr.), Dyar, Ent. News, xxii, 1911, p. 199.

Diatraea saccharalis grenadensis, Dyar, Ent. News, xxii, 1911, p. 200.

Diatraea saccharalis obliteratellus (Zell.), Dyar, Ent. News, xxii, 1911, p. 200.

Diatraea saccharalis crambidoides (Grt.), Dyar, Ent. News, xxii, 1911, p. 200; Holloway, J. Agric. Res., vi, 1916, p. 621, ff. (larva); Heinrich in U.S. Dept. Agr. Bull. 746, 1919, ff. (nec *Chilo crambidoides*, Grt., Canad. Ent., xii, 1880, p. 15, = *Diatraea crambidoides*, Grt.).

Diatraea pedidocta, Dyar, Ent. News, xxii, 1911, p. 201; Dyar & Heinrich, *loc. cit.*

Diatraea sacchari brasiliensis, van Gorkum & de Waal, Bol. Est. Exp. de Canna de Assucar de Escada, Pernambuco, i, 1913, p. 181.

Diatraea incomparella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 13.

The use of the name *saccharalis*, Fabr., for the present species has hitherto been largely arbitrary. No type is known to us, and the original description might be interpreted as being applicable not only to a number of different species of *Diatraea*, but to other Crambine moths as well. The present writer considered it necessary to remove as far as possible any doubts as to the correct application of the name proposed by Fabricius, and therefore made a detailed study of the early literature. This is particularly desirable since Howard (Insect Life, v, 1891, p. 95) suggested Dutch Guiana as the country of origin of *Phalaena saccharalis*, for other species of *Diatraea* occurring in that country are liable to be confused with that which to-day we recognise as *saccharalis*. Actually, Howard's statement is as follows: "This insect was described by Fabricius (Entomologia systematica, vol. III, part 2, p. 238) from South America, no more definite locality being given. The probabilities are, however, that he refers to Dutch Guiana on account of the early settlement of that country and from the fact that he refers to a figure of the larva by Myhlenfels. . . . He describes the larva as six-footed, of a pale hyaline colour, and with the head and eight spots brown. The larval description, however, is drawn from a figure by Myhlenfels, which may have been inaccurate." The figure in question together with

illustrations of the pupa and imago, accompanied an article which was published by Fabricius in the same year as his original description of *Phalaena saccharalis*, under the title " Beskrivelse over den skadlige sukker og bomuldsorm i Vest Indien . . ." (Skrift. af Naturhist. Selskabet, iii, 2, pp. 63–67, t. vii, f. 1*). A copy of this rare work is in the British Museum (Natural History), and the writer finds that the figures give a passable representation of the common West Indian sugar-cane borer which we know as *Diatraea saccharalis*, Fabr., and which is obviously the same insect as that described from St. Vincent by Guilding in 1828 as *Diatraea sacchari*.

The identity of Guilding's species with that of Fabricius seems to have been known to several of the earlier entomologists, including Westwood (1856), Guenée (1862) and Zeller (1881). Westwood and Zeller, however, thought the New World cane borer was the same as that of Mauritius, which was described as *Proceras sacchariphagus* by Bojer in 1856, and Guenée was under the impression that the cane borer of Réunion, which he calls *Borer saccharellus*, was the same insect. Zeller, however, does not agree with Guenée, and, after a scathing criticism of the use of the word " borer " as a generic name, shows that Guenée's insect is distinct. To-day, we recognise the cane borer of Mauritius as distinct also, and there is no evidence that the species known as *D. saccharalis* occurs in the Old World.

Hampson's error in considering *Chilo crambidoides*, Grt., to be the same as *D. saccharalis* has been followed by all authors who have dealt with the synonymy of the latter, and has led to considerable confusion in the literature. The writer has examined Grote's type (in the British Museum) and finds it to be distinct from *saccharalis* ; he therefore raises *crambidoides* to specific rank again (see p. 20).

D. incomparella, Dyar & Heinr., is sunk as a synonym of *saccharalis* on the evidence afforded by a careful study of the original description together with an examination of a paratype female presented by Dr. Heinrich. The long series of *saccharalis* before the writer includes several specimens of both sexes with markings as in the form separated as *incomparella*, but which cannot be differentiated specifically from the Fabrician species, and numerous transitional specimens have been seen merging into the typical form of the latter.

D. saccharalis is extremely variable in size and coloration, and it would be difficult to give a comprehensive description of its external characters that would definitely exclude other species. The insect is, however, so well known and so widely distributed that a detailed account of its coloration and markings in their various modifications would be superfluous here ; it should be noted, however, and taken as a guide to identification, that among the 426 specimens examined by the writer in the course of the present studies the shape of the frons is constant, being convex, somewhat bulging, and without any tendency to be produced into a point at the apex (fig. 2, A–B). Nevertheless, the genitalia are the only sure criterion for diagnosis, and their examination should be resorted to wherever there is an element of doubt. These organs are described in detail and figured by Dyar & Heinrich in their 1927 revision of the genus. The male genitalia are distinct from those of all other species, but those of the female might possibly be confused with several other forms, but as each of the latter is quite distinct in other respects (see Key) further observations are unnecessary.

A considerable literature has accumulated upon this species, its habits and life-history, food-plants, natural enemies, and economic status, in different countries, which it would be impossible to review even briefly in these pages. In spite of this mass of published data, however, the writer believes that there is no other insect pest of such importance upon which so little really fundamental knowledge is available.

* This reference was latinized by Fabricius (Suppl. Ent. Syst., 1798, p. 439) as follows : " Act. Soc. Hist. Nat. Hafn. 3, tab. fig."

The larva has been described and figured by several writers, but the principal references are those of Holloway (1916), Heinrich in Holloway & Loftin (1919), Forbes (1920), and Heinrich in Holloway, Haley & Loftin (1928).

126 ♂♂, 295 ♀♀ (in all collections examined) :—U.S.A. : Enterprise, Florida ; Brownesville, Texas, ii–iv.1925 (*E. Piazza*). MEXICO : 1896–97 (*Notni*) ; Jalapa (*M. Trujillo*) ; Jalapa, 1893 (*Gomez*) ; Orizaba, iii-iv.1896 (*W. Schaus*). GUATEMALA : Cerro Zunil, 4,000–5,000 ft., El Tumbador, Las Mercedes, 3,000 ft., V. de Atitlan, 2,500–3,000 ft., and Senahu, Vera Paz (*Champion*). CUBA : Jaronú, reared from larvae in sugar-cane, x.1929 & iv.1930 (*J. G. Myers*). JAMAICA : (*Jackson*) ; reared from larvae in sugar-cane, i–ii.1930 (*J. G. Myers*). SANTO DOMINGO : reared from larvae in sugar-cane, 1929 (*H. T. Osborn*). PORTO RICO : Aguirre, reared from larvae in sugar-cane, 1926 (*H. E. Box*), 1930 (*H. T. Osborn*) ; ST. THOMAS : (*Moritz*). ANTIGUA : (*C. A. Barber*) ; 16.ii.1904 (*Nicoll*) ; reared from larvae in sugar-cane 10.iv.1930 (*J. G. Myers*). ST. KITTS : (*J. J. Quelch*). DOMINICA : ii.1897 ; xi.1904-vi.1905 (*E. A. Agar*). ST. VINCENT : iii.1897 (*Rendall*) ; (*H. H. Smith*). GRENADA : St. Andrew's, 170 ft., iv.1890 ; Mount Gay Estate (*H. H. Smith*). BARBADOS : (*R. E. Frampton*) ; reared from larvae in sugar-cane, iii.1927 (*H. E. Box*), 1930 (*R. W. E. Tucker*). TRINIDAD : (*Dyer*) ; reared from larvae in sugar-cane, i–ii. 1929 (*J. G. Myers*) ; xi.1929 (*F. W. Urich*) ; Caparo, xi.1905 (*S. M. Klages*). COLOMBIA : Coca, Upper Rio Napo, v-vii.1899 (*W. Goodfellow*). VENEZUELA : Macuto, Caracas, Caracas Valley, and near Lago Valencia, reared from larvae in sugar-cane (*H. E. Box*) ; Ciudad Bolivar, vi–ix.1898 (*S. M. Klages*) ; La Union, La Vuelta and Cuyapa, Rio Caura, 1902–03 (*Klages*) ; Suapure, ii–iii.1899 (*Klages*). BRITISH GUIANA : (*J. Rodway*) ; R. Demerara ; Christianberg ; Bartica, vii.1901 ; Potaro R., 5–19.v.1901 (*W. J. Kaye*). DUTCH GUIANA : Ephrata, ii.1892 (*C. W. Ellacombe*). FRENCH GUIANA : St. Jean du Maroni (*E. Le Moult*). BRAZIL : Maranhao (*Miss Orchard*) ; Goyaz town, i.1906 (*G. A. Baer*) ; Novo Friburgo ; Rio de Janeiro ; Santos ; Santa Catharina (*Scheidentl.*) ; São Paulo ; Piquete, São Paulo, 600–900 m., 20.i.1901 (*Robert*) ; Minas Geraes, 14.xi.1900 (*Kennedy*) ; San Jacintho Valley, Theophilo Ottoni, Minas Geraes, spring 1907, at light (*S. F. Birch*) ; 15 m. S. of Corumbá, Matto Grosso, 650 ft., 19.iv.1927 (*C. L. Collenette*) ; Castro, Parana, 950 m. (*E. D. Jones*) ; Iguassu, Parana, 15.x.1921 ; AMAZONS REGION : Para (*A. M. Moss*) ; Lower Amazons, i–ii.1896 (*E. E. Austen*) ; Prainha, 14.iii.1873, at light ; R. Madeira, 9.v.1913 (*R. V. Moffat*) ; R. Madeira, vii–viii (*Fassi*) ; Humayta and Allianca, R. Madeira, 1906–1907 (*W. Hoffmann*) ; Manaos, ix.1906 (*M. de Marthan*) ; Manaos to Yutahi R. (*M. Stuart*) ; R. Solimoes, W. Santa Cruz, 9.xii.1874 ; Yapatiny, R. Parmo, 29.ix.1874 ; Marapata, R. Negro, 30.xii.1874 ; Teffe, i. & x.1907 (*M. de Marthan*) ; Fonte Boa and Codajas, v–vi.1906 & iv.1907 (*S. M. Klages*) ; R. Jurua, 6.ii.1874 ; Juhuty, iv–v.1905 (*M. de Marthan*) ; Amaz. sup. (*Michael*). PARAGUAY : Sapucay, 4.ix.1901 & 15.ix.1903 (*W. Foster*) ; Alto Paraguay, viii.1904 (*J. Steinbach*) ; San Bernardino (*K. Fiebrig*). ARGENTINA : Misiones ; Corrientes, xii.1898 (*Stuart*) ; Goya, Corrientes (*Perrins*) ; Paraná, Entre Rios ; La Soledad, Entre Rios, 1901–1905 (*E. A. Britton*) ; Villa Ana, Santa Fé, 1923–1927 (*K. J. Hayward*) ; Germania, Santa Fé, reared from larva in sugar-cane, iv.1928 (*H. E. Box*) ; Buenos Aires (city), at light (*J. Bosq*) ; Belgrano ; Ocampo, El Chaco, xi.1905 (*S. Venturi*) ; Tucumán (city and province), 1902 & 1903 (*Dinelli*), (*L. Monetti*), (*J. Steinbach*) ; Tucumán, reared from pupae in maize, iii.1929 (*H. A. Jaynes*) ; Güemes, Prov. Salta, reared from larvae in sugar-cane, i.1929 (*H. A. Jaynes*) ; San Pedro and Ledesma, Prov. Jujuy, reared from larvae in sugar-cane, iii–iv.1928 (*H. E. Box*). BOLIVIA : Buenavista, 750 m., vii.1906–iv.1907 (*J. Steinbach*). PERU : Callanga, 1,500 m., and Vilcanota, 3,000 m., Prov. Cuzco (*O. Garlepp*) ; Barranco, nr. Lima, iv–v.1913 (*H. O. Forbes*) ; Pisco (*Hofmann*) ; Rio Pacaya, vi–ix.1912 ; La Oroya, R. Inambari, 3,100 ft., iii.1905 and xii.1905 (*G. Ockendon*) ; Tinguri, Carabaya, 3,400 ft., viii.1904 (*G. Ockendon*) ; Iquitos, 1893

(*Stuart*). ECUADOR: Paramba, ii–vi.1897 (*Rosenberg*); Quevedo (*v. Buchwald*); Chimbo, 1,000 m., viii. 1897 (*Rosenberg*); S. Domingo de los Colorados, x.1898 (*W. Goodfellow*); R. Durango, 350 ft., vi. 1901 (*Fl. & Mik.*).

Types examined :—

Crambus lineosellus, Walk., ♂, in British Museum ; Honduras.

Crambus leucaniellus, Walk., ♀, in British Museum ; St. Domingo.

Chilo obliteratellus, Zell.—Zeller states " Patria : Brasilia (Kollar)." The writer has seen two specimens from Brazil, labelled " *Chilo obliteratellus* " by Zeller himself ; these are in the Berlin Museum, one from " N. Friburgo " and the other " Amaz. sup. (*Michael*)." It is unlikely that either of them is the type. Another Brazilian specimen from the Zeller collection was incorporated in the Felder collection, now in the Tring Museum ; this is the actual specimen figured by Felder & Rogenhofer, and is labelled " Nov. cxxxvii, f.24, Chilo obliteratellus, Zell. Amaz. ♀ " in Felder's ms. This is probably the type.

12. Diatraea tabernella, Dyar (Pl. iii, fig. 7).

Diatraea saccharalis tabernella, Dyar, Ent. News, xxii, 1911, p. 200 ; Proc. U.S. Nat. Mus., xlvii, 1915, no. 2050, p. 319.

Diatraea tabernella (Dyar), Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 15, f. 7.

Chilo obliteratellus, Zeller, Ent. Zeit., 33, 1872, p. 465 (part) ; Hor. Soc. Ent. Ross., xiii, 1877, p. 14 (Exot. Microlep., p. 12) (part ?) (nec *Chilo obliteratellus*, Zell., Chilonid. et Crambid. gen. et spp., 1863, p. 8, = *D. saccharalis*, Fabr.).

Diatraea obliteratella, Zeller, Hor. Soc. Ent. Ross., xvi, 1881, p. 163 (part), t. xi, f. 5 *b*, ♀ (not f. 5 *a*, ♂, = *D. saccharalis*, Fabr.).

Zeller gives very exact descriptions of this moth in his papers of 1872 and 1881, based upon specimens collected in Colombia (including that part which to-day is known as Panama). He makes reference to the tuft of hairs on the hind tibia of the male, and also describes the characteristic frons (fig. 3, *g*) (" Die Stirn ist bei dieser Art . . . mit einer kurzen, kegelförmigen Auftreibung versehen, deren Anwesenheit man auch ohne Abschuppung erkennt. An einzelnen Exemplaren ist aber diese Auftreibung nur beulenförmig "*). Unfortunately, however, Zeller attributed these specimens to the same species that he had previously (1863) described from Brazil as *Chilo obliteratellus*, to-day recognised as synonymous with *D. saccharalis*, for which reason we are unable to adopt the name here.

The British Museum series of *tabernella* includes 10 ♂♂ and 5 ♀♀ from the Zeller Collection, taken by Petersen in Colombia ; they are labelled " Diatraea obliteratella " or " Diathraea obliterata " (*sic*) in Zeller's handwriting, and undoubtedly formed part of those to which he referred in 1881 ; a single male *saccharalis* from Colombia is similarly labelled by Zeller, so that we may presume Petersen's lot of specimens to have included both species, though Zeller recognised but one. Of the very excellent coloured figures illustrating Zeller's 1881 article, that of the female (fig. 5, *b*) undoubtedly represents *tabernella*, but the male (fig. 5, *a*) was probably drawn from a specimen of *saccharalis* ; unfortunately the legs are not included in the latter figure, otherwise there would be no doubt as to the identity of its subject.

Whilst both sexes of *tabernella* bear a superficial resemblance to *saccharalis*, the closest relative would seem to be *pedibarbata* (Eastern S. America) ; the characters presented in the Key should enable the species to be separated without any difficulty.

Dyar & Heinrich figure the characteristic male genitalia of *tabernella*, but state that the female genitalia are " as in *saccharalis*." To the present writer several

* I have not seen a specimen of *tabernella* in which the term " beulenförmig " (pimple-shaped) could be applied to the frons. Possibly Zeller had yet other species before him at the time. —H. E. B.

differences are apparent in the female genitalia of these two species, notably in the shape and degree of chitinization of the lateral lobes of the shield below (in front of) the genital opening, and in the puncturation of the posterior fold and the area between this fold and the genital opening itself.

18 ♂♂, 13 ♀♀ (B.M., T.M., Z.M.U.B.) :—BRITISH HONDURAS : Punta Gorda, vii.1913 & ii.1915 (*R. Norton*). PANAMA : Chiriqui (*Ribbe*) ; V. de Chiriqui, 2,000–3,000 ft. (*Champion*) ; Bugaba, 800–1,500 ft. (*Champion*) ; Rio Trinidad, 15–31.iii. 1912 (*A. Busck*). COLOMBIA : (*Petersen*) ; R. Magdalena, 18.i.1871 ; Condoto & Rio Condoto, Choko Prov., 19. xii. 1914 (*H. G. F. Spurrell*).

13. **Diatraea pedibarbata,** Dyar (Pl. v, fig. 9).

Diatraea pedibarbata, Dyar, Ent. News, xxii, 1911, p. 202 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 2, f. 4.

A medium-sized species both sexes of which closely resemble *tabernella*, Dyar (Central America, Colombia). The genitalia, however, are characteristic, though Dyar & Heinrich state that those of the female are " similar to those of *instructella*, except that bursa is longer." The latter species is known only by the unique female type, so that it is desirable to figure the genitalia of *pedibarbata*.

5 ♂♂, 7 ♀♀ (T.M.) :—DUTCH GUIANA ; Ephrata, ii.1892 (*C. W. Ellacombe*) ; Paramaribo, xi–xii.1892 (*Ellacombe*). FRENCH GUIANA : St. Laurent du Maroni (*E. Le Moult*). ARGENTINA : Paraná, Entre Rios.

The example from Argentina is much faded, but the markings of the fore wing and the genitalia render the determination fairly certain ; the frons in this specimen is without the sharp point found in the others (*cf.* fig. 3, *e*, *h*).

14. **Diatraea guatemalella,** Schs.

Diatraea guatemalella, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 138 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 14, ff. 6, 55.

A medium to large species with the fore wing rather light coloured (pinkish buff to ochraceous buff), with characteristic markings and unmistakable genitalia..

1 ♂, 4 ♀♀ (B.M., T.M.) :—MEXICO : Teapa, Tabasco (*H. H. Smith*). GUATEMALA : Cayuga (*Schaus & Barnes coll.*). COSTA RICA : Irazu, 6,000–7,000 ft. (*Champion*) ; Esperanza.

The example from Mexico is rather small (expanse 30 mm., compared with 36–38 mm. of typical females) and very much faded ; the genitalia, however, agree with this species.

The specimens in the Godman-Salvin collection are erroneously referred to *D. saccharalis* in the " Biologia Centrali-Americana."

15. **Diatraea indigenella,** Dyar & Heinr. (Pl. ii, figs. 1, 2 ; Pl. iv, fig. 3).

Diatraea indigenella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 13, f. 51.

The original description, based upon 5 ♀♀ from Popayán, Colombia, is not sufficient to enable the species to be determined with accuracy. It is there compared with *fuscella*, Schs. (Central America), which it certainly resembles to some extent, both species being dark coloured and with the fore wing rather broad. Now that the male *indigenella* is known, the species may be re-described, as follows :—

♂. Palpus warm buff, streaked with wood-brown to buffy brown at sides and below. Antennal shaft honey-yellow with sparse warm buff scales. Head vinaceous

buff tinged with avellaneous to wood-brown. Thorax wood-brown tinged with Verona brown, especially at sides. Tergum drab to buffy brown with some scattered avellaneous scales, proximal two segments tawny. Pectus pinkish buff tinged with tawny olive. Legs the same. Venter the same. Fore wing vinaceous buff to avellaneous suffused with mummy-brown, especially on costa, on a broad triangular patch below costa at apex, interneurally on outer margin and on a broad median area above vein 1c from base to apex ; the veins slightly infuscate ; narrow vinaceous buff to avellaneous lines of scales in the interneural spaces, contrasting with the mummy-brown suffusion ; a fuscous blackish discocellular dot ; a narrow, rather elongate, cinnamon-buff streak from middle to just beyond apex of cell ; two oblique lines, the first consisting of short fuscous streaks on and between the veins, from vein 10 in a wide curve around and below the cell, where it broadens into a median fuscous patch which gradually narrows and fades as it bends to run into inner margin at a point one-third its length from base ; the second resolved into separate fuscous dots on the veins, extending from the junction of veins 8 and 9 just below the dark apical shade, in a wide curve to vein 1c, with a final less distinct dot on inner margin just beyond middle ; a terminal series of fuscous blackish interneural dots. Hind wing avellaneous tinged with buffy brown, rather lighter (vinaceous buff to avellaneous) towards base ; an irregular fuscous terminal line, thickened interneurally to form dots. Underside of fore wing snuff-brown, costa and outer margin warm buff tinged with tawny olive ; the veins slightly infuscate ; discocellular dot faint, brownish ; terminal dots distinct, blackish ; of hind wing similarly coloured ; traces of fuscous terminal dots below apex. Expanse 30 mm.

♀. Similar, larger, the colouring of fore wing generally lighter ; ground-colour warm buff to ochraceous buff tinged with clay to tawny olive, the markings similar to but less contrasting than in the ♂ ; hind wing light ochraceous buff tinged with clay-colour to tawny olive.

The frons is strongly convex, with a sharp point at the apex (fig. 3, *j*).

2 ♂♂, 3 ♀♀ (B.M., T.M.) :—Colombia : Torne, Cauca, 1–15.ii.1907 (*Paine & Brinkley*) ; Guabinas, Rio Cauca, i.1908 ; Cañon del Tolima, 1,700 m., xii.1909 & iii.1910.

16. **Diatraea fuscella,** Schs. (Pl. v, fig. 13).

Diatraea fuscella, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 139 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 22, ff. 15, 61.

A rather dark-coloured, broad-winged species suggestive of *D. indigenella*, Dyar & Heinr. (Colombia).

The frons is rather like that of *indigenella*, but is more strongly convex and more sharply pointed (fig. 3, *k*).

8 ♀♀ (B.M.) :—Mexico : Teapa, Tabasco (*H. H. Smith*). Costa Rica : Irazu, 6,000–7,000 ft. (*Rogers*).

The above are all part of the Godman-Salvin collection ; they are erroneously referred to *D. saccharalis* in the " Biologia Centrali-Americana."

The species is also known from Guatemala.

17. **Diatraea magnifactella,** Dyar.

Diatraea magnifactella, Dyar, Ent. News, xxii, 1911, p. 201 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 14, ff. 3, 52.

A large distinctive form, notable for the rather dark colour of the hind wing in both sexes. The frons is characteristic (fig. 3, *l*).

This species appears to be confined to Mexico, in which country, however, it has a wide range, judging by the records published by Dyar & Heinrich. The larva is stated to attack sugar-cane, but we have no knowledge of the bionomics or economic status of this species.

Van Zwaluwenburg's reference to the occurrence of *D. canella* as a pest of sugar-cane in Mexico (J. Econ. Ent., xix, 1926, p. 664) is evidently an error for *magnifactella*.

5 ♀♀ (B.M., T.M., Z.M.U.B.) :—MEXICO : Cuernavaca (*W. Schaus*) ; Orizaba (*Schaus*) ; Fortin, 1896–97 (*Notni*).

18. Diatraea obliqualis, Hamps. (Pl. v, fig. 4).

Diatraea obliqualis, Hampson, Ann. Mag. N.H., (9) iii, 1919, p. 543.

A small species, described from a single female (expanse 22 mm.) in the British Museum, from Goya, Prov. Corrientes, Argentina (*Perrins*), coloured as in *brunnescens*, sp. n. (Venezuela) and *incertella*, sp. n. (Rio de Janeiro) ; the latter, known only by the unique type, may prove to be the male of *obliqualis*. The genitalia of *obliqualis* resemble those of two females from Trinidad here referred to *D. minimifacta*, and the general aspect of the two species is similar ; they can be separated, however, by the structure of the frons, which is smoothly rounded and only slightly convex in the Trinidad form (fig. 3, *c*), but strongly produced to a conical point in *obliqualis* (fig. 3, *m*).

D. obliqualis resembles *minimifacta* in venation, both wings having veins 4 and 5 stalked together, though for a greater distance in the latter than in the former (*cf.* fig. 5, G, H). On the other hand, *brunnescens* and *incertella*, which both resemble *obliqualis* in general aspect and in the shape of the frons, have veins 4 and 5 of the fore wing free or at most just united together at their bases (fig. 5, E, F) ; in the hind wing veins 4 and 5 are stalked for some distance in *incertella* and in one specimen of *brunnescens*.

A female in the British Museum, labelled " Argentina, Villa Ana, Santa Fé, 26.xi.1923 (*K. J. Hayward*)," agrees exactly with *obliqualis* in size, coloration and frontal structure ; the genitalia (Pl. v, fig. 8), however, are very different, and for the present the specimen is included among the *spp. incertae* (see footnote, p. 12).

19. Diatraea brunnescens, sp. nov. (Pl. v, fig. 1).

♀. Palpus light buff tinged with warm buff, streaked at sides and below with avellaneous. Antennal shaft honey-yellow with sparse light buff scales. Head light buff, sometimes tinged with warm buff ; a wood-brown median line sometimes present on vertex. Thorax light buff tinged with warm buff, tinged with wood-brown in front and at sides ; a wood-brown median line sometimes present. Tergum light buff to warm buff, proximal two segments ochraceous tawny. Pectus light buff tinged with warm buff. Legs the same. Venter cartridge-buff to light buff. Fore wing with basal two-thirds, except for a streak along vein 1c from base, ochraceous buff strongly tinged with ochraceous tawny, sometimes tinged with wood-brown on costa ; apical third and inner margin below vein 1c at base with a ground-colour of light buff tinged with buff-yellow, strongly suffused with mustard-yellow to yellow-ochre or tawny, these colours tending to run into lines on and between the veins ; the cell and an area beyond, between veins 5 and 6, mustard-yellow tinged with yellow-ochre ; a fuscous blackish discocellular dot ; two oblique bands of warm sepia, the first rather broad, diffused and indistinctly contrasting, from a dark apical shade below vein 10 near apex, in an almost straight line to inner margin at a point about one-third its length from base ; the second narrower, more sharply defined, from near apex of vein 7 to inner margin at a point about two-thirds its length

from base; a terminal series of blackish interneural dots, those above veins 2 and 3 larger and more conspicuous than the others. Hind wing whitish to cartridge-buff tinged with pinkish buff to light buff, slightly tinged with warm buff on costa, at apex, and interneurally on outer margin. Underside of fore wing drab, sometimes darker on a triangular patch at apex below vein 10, much lighter (pinkish buff) on outer margin and on a streak from middle of cell to outer margin between veins 5 and 6; discocellular dot faint, terminal dots obsolete; of hind wing cartridge-buff tinged with pinkish buff on costa and outer margin below apex. Expanse 16·5–22 mm.

The frons is similar to that of *D. obliqualis*, Hamps. (fig. 3, *m*).

VENEZUELA: Ciudad Bolivar, various dates vi–x.1898 (*S. M. Klages*).

Holotype ♀ in Tring Museum; paratypes, 5 ♀♀, in Tring Museum, British Museum and U.S. National Museum.

The above description applies quite well to *D. obliqualis*, Hamps. (Argentina), and to *incertella*, sp. n. (Rio de Janeiro), though in the unique type of the former the costa of the fore wing is much less rounded than in *brunnescens* and *incertella*. The venation of the fore wing of the six specimens of *brunnescens* examined is similar, in that veins 4 and 5 do not unite at their bases (fig. 5, E), but in the hind wing one specimen has veins 4 and 5 stalked together for quite half their length, whereas the remaining specimens have these veins free or at most just united at their bases.

D. minimifacta, Dyar, which also occurs in Venezuela, is somewhat similar in general aspect but can be separated from *brunnescens* by the shape of the frons, which is smooth and gently rounded, and not projecting between the eyes (fig. 3, *c*).

The single male from Rio de Janeiro, described below as *incertella*, sp. n., may prove to be the same as *brunnescens*, though it is equally possible that it is the male of *obliqualis*.

20. Diatraea incertella, sp. nov. (Pl. i, figs. 16, 17).

A single male agrees with the above description of *brunnescens*, sp. n., and also with *obliqualis*, Hamps., except that the general colour of the fore wing is *very slightly* darker; the costa of the fore wing is curved as in *brunnescens*. The venation is intermediate, the fore wing having veins 4 and 5 just united (fig. 5, F), but not stalked together, and the hind wing having these veins stalked for about half their length.

Since there is nothing to indicate with any degree of certainty to which of the above mentioned species this male pertains, and since it is equally possible that it may be distinct from either of them, it is considered advisable to treat it as new.

BRAZIL: Rio de Janeiro.

Holotype ♂ in Tring Museum.

21. Diatraea umbrialis, Schs.

Diatraea umbrialis, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 139; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 23.

Unknown to the writer. Known by the type and one other female in the U.S. National Museum, from St. Jean and St. Laurent, Maroni River, French Guiana.

22. Diatraea maronialis, Schs.

Diatraea maronialis, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 139; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 23, ff. 17, 64.

Unknown to the writer. A distinctively marked species, known in both sexes, from French Guiana and the Amazons region. Types in U.S. National Museum.

23. Diatraea continens, Dyar (Pl. ii, figs. 3, 4 ; Pl. v, fig. 12).

Diatraea continens, Dyar, Ent. News, xxii, 1911, p. 202 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 15, f. 50.

Hitherto known only by the single female type in the U.S. National Museum, from Castro, Parana, Brazil.

Two specimens are before the writer :—BRAZIL : Castro, Parana, 950 m., 1 ♀ (*E. D. Jones*). ARGENTINA : Buenos Aires, 1 ♂ (*H. Wilkinson*).

The original description is rather meagre, but the additional notes and the figure of the genitalia given by Dyar & Heinrich render our identification sure. Now that the male is forthcoming, the species is re-described, as follows :—

♂. Palpus cartridge-buff tinged with pinkish buff, streaked with avellaneous to wood-brown at sides and below. Antennal shaft honey-yellow with sparse cartridge-buff scales. Head cartridge-buff tinged with pinkish buff, slightly tinged with warm buff on top of frons and vertex. Thorax pale pinkish buff tinged with pinkish buff, avellaneous in front and at sides. Tergum pale pinkish buff tinged with warm buff, proximal two segments ochraceous buff. Pectus cartridge-buff. Legs cartridge-buff to light buff, tinged with some warm buff. Venter whitish to cartridge-buff. Fore wing with ground-colour whitish tinged with pale pinkish buff, tinged with pinkish buff on costa to near middle and on inner margin, a pale orange-yellow suffusion at apex of cell and beyond, and also on outer margin below vein 7 ; an olive-brown shade bordering on the yellowish suffusion and extending from base of vein 6 just beyond cell, to apex, completely obscuring the ground-colour and to some extent the vein linings ; the veins lined with wood-brown, becoming lighter (cinnamon-buff to cinnamon) towards outer margin ; interneural spaces with warm buff to cinnamon lines ; a fuscous blackish discocellular dot ; two oblique wood-brown lines, composed of streaks on and between the veins, the first rather broad and somewhat irregularly wavy, extending as a continuation downwards and inwards of the dark apical shade, and continuing in a slight curve to vein 3 just below discocellular dot, then bending to run into inner margin near base ; the second line narrower, in a gentle curve from vein 7 near apex to vein 1c, then running into and along inner margin to merge into the base of the first line ; a terminal series of fuscous blackish interneural dots. Hind wing whitish, tinged with pinkish buff on costa and at apex. Underside of fore wing light buff strongly overspread with buffy brown except on costa, outer margin, inner margin below vein 1c and on a streak from middle of cell to outer margin between veins 5 and 6 ; discocellular dot faint, brownish ; terminal dots distinct, blackish ; of hind wing cartridge-buff tinged with pinkish buff, tinged with buffy brown on costa and at apex. Expanse 29·5 mm.

♀. Similar, larger, colouring similar to and equally intense as that of the ♂. Hind wing whitish to cartridge-buff, tinged at apex with pinkish buff ; a distinct fuscous terminal line, extending and gradually increasing in intensity from just below apex to near vein 3, tending to form blackish dots interneurally. Underside of hind wing cartridge-buff tinged with pinkish buff on costa and on the veins ; a terminal series of fuscous blackish interneural dots. Expanse : of the type in the U.S. National Museum, 29 mm. ; of the specimen in the British Museum, 43·5 mm.

The frons is conically produced, with a sharp point at the apex (fig. 3, *n*).

24. Diatraea bellifactella, Dyar.

Diatraea bellifactella, Dyar, Ent. News, xxii, 1911, p. 205 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 26, ff. 22, 67.

Hitherto known by the male and female types in the U.S. National Museum, from São Paulo and Castro, Brazil, respectively. The distribution of the specimens

before the writer indicates that the species has a wide range in South America; its occurrence in Grenada and Trinidad is particularly interesting.

Dyar & Heinrich state that this is "a rather large species near *lineolata* and *schausella*. . . ." As a matter of fact *bellifactella* shows very little, if anything, in common with these species to the exclusion of others, and its general characters and the peculiar genitalia of both sexes indicate rather that *bellifactella* belongs to a unique category and cannot be compared with any member of the genus hitherto described.

Externally, *D. bellifactella* rather closely resembles *luteella*, sp. n., and recourse to an examination of the genitalia is necessary to separate definitely the females of these two forms; some general characters, useful in aiding a specific diagnosis, are given in the Key. It is very curious that two species so closely related on external characters should have such distinct types of genitalia. The frons (fig. 3, *o*) is rather similar to that of *luteella* (fig. 3, *p*), but the apex is more truncate.

6 ♂♂, 6 ♀♀ (B.M., T.M., Z.M.U.B.):—GRENADA: Fort George, ix.1891. TRINIDAD: (*F. W. Jackson*); Port of Spain (*F. Birch*). BRAZIL: Pernambuco; Rio de Janeiro; São Paulo; Anhangahy, São Paulo, xii.1926 (*E. Spitz*); Iguassu, Parana; Castro, Parana, 950 m. (*E. D. Jones*); Codajas, Upper Amazons, iv.1907 (*S. M. Klages*). BOLIVIA: Buenavista, 750 m., vii–x.1906 (*J. Steinbach*). PERU: La Union, R. Huacamayo, Carabaya, 2,000 ft., xii.1904 (*G. Ockendon*).

25. Diatraea luteella, sp. nov. (Pl. i, figs. 7, 8; Pl. iv, fig. 10).

♂. Palpus cream-colour to maize-yellow, streaked with avellaneous at sides and below. Antennal shaft honey-yellow with sparse light buff scales, tinged with ochraceous buff on basal segments. Head light buff tinged with warm buff to ochraceous buff; an indefinite slightly darker median line on vertex. Thorax warm buff strongly tinged with ochraceous buff. Tergum light buff slightly tinged with warm buff, proximal two segments ochraceous buff tinged with cinnamon. Pectus light buff tinged with warm buff. Legs the same. Venter light buff. Fore wing cream-colour tinged with maize-yellow, especially on costa, strongly tinged with ochraceous tawny on an indefinite streak in base of cell; the veins lined with warm buff to ochraceous buff, those at tornus ochraceous tawny; similar, but lighter and more indefinite, lines between the veins on outer margin; a fuscous brownish (bone-brown) triangular shade below costa at apex; a fuscous blackish discocellular dot; a light (cream-colour) streak from middle of cell to outer margin between veins 5 and 6; two oblique well-defined fuscous lines, composed of short elongate streaks on and between the veins, the first extending as a continuation downwards and inwards of the dark apical shade, from apex to vein 8, along this vein to about halfway between apex of cell and outer margin, then rather broadly bowed (concavity basad) around and below the cell to and along vein 3 just below the discocellular dot, then abruptly and sharply bent to run into a dark shade below vein 1c near base; the second line extending and widening gradually from vein 5 near apex (just below the light streak from cell) to inner margin below apex of vein 1c; a terminal series of fuscous blackish interneural dots. Hind wing whitish tinged with cream-colour, tinged with light buff and some warm buff along costa and outer margin below apex. Underside of fore wing light buff tinged with warm buff except in cell and a streak beyond, and on inner margin below vein 1c, tinged with ochraceous buff on costa and at apex; discocellular and terminal dots faint; of hind wing cartridge-buff tinged with light buff on costa and at apex. Expanse 24 mm.

♀. Similar, larger, the general coloration paler and more yellowish. Fore wing with the veins and the dark areas much less distinct and contrasted than in the ♂; first oblique line very indistinct but indicated by slight thickenings of the vein linings,

especially below the cell; second oblique line resolved into a row of separate (faint) dots on the veins, extending in a wide curve from vein 6 near apex to vein 1c near apex. Expanse 28·5 mm.

In both sexes the frons is prominent, strongly conically produced with the apex rather abruptly truncate (fig. 3, *p*).

N.W. Ecuador: Rio Cayapas, 1 ♂, 2 ♀♀.

Holotype ♂, and allotype ♀, in Tring Museum.

One female in the Tring Museum, similarly labelled, differs from the type material in having vein 10 of the fore wing stalked with 8+9 for about half its length (fig. 5, D); the specimen undoubtedly pertains to this species, but for obvious reasons is not considered a paratype.

D. luteella superficially resembles *bellifactella*, but can be separated by the characters given in the Key; the genitalia of these two species, however, are very distinct from those of *bellifactella*.

26. Diatraea suffusella, sp. nov. (Pl. v, fig. 14).

♀. Palpus light buff tinged with vinaceous buff, streaked with wood-brown at sides and at apex. Antennal shaft honey-yellow with sparse vinaceous-buff scales. Head pinkish buff tinged with cinnamon-buff, slightly tinged with cinnamon on vertex. Thorax pinkish buff tinged with cinnamon-buff. Tergum pale pinkish buff tinged with cinnamon-buff, somewhat infuscate, proximal two segments ochraceous buff. Pectus pale pinkish buff tinged with cinnamon-buff. Legs the same. Venter pale pinkish buff tinged with pinkish buff. Fore wing light ochraceous buff uniformly suffused with tawny olive, producing a "greyish brown" colour (under the microscope the individual scales are seen to be bi-coloured, light on their bases and dark on their apices, producing a very characteristic appearance), except on apical one-third of costa and on a streak from middle of cell to outer margin between veins 5 and 6, which are light ochraceous buff without a dark tinge; a small rather ill-defined triangular fuscous shade below costa at apex; a fuscous blackish discocellular dot; the veins infuscate, but the following rather strongly so: the median vein to base of vein 3, the fork of veins 4 and 5 for a short distance along these veins, and a small "trident" on the bases of veins 7, 8+9 and 10, at apex of cell; two very faint oblique fuscous lines, the first (of which the strongly infuscate parts of the veins form part), composed of short streaks or elongate dots on the veins, from vein 7, just below the dark apical shade, in an almost straight line to vein 1c about one-third its length from base; the second resolved into rounded dots on the veins, from vein 6 near apex to vein 1c about two-thirds its length from base; a terminal series of faint fuscous interneural dots, that on the inner angle above vein 2 larger and blacker than the others. Hind wing whitish slightly tinged with pale pinkish buff, tinged with pinkish buff on costa and outer margin below apex. Underside of fore wing drab to avellaneous; basal part of costa light buff; a light buff streak from middle of cell to beyond, between veins 5 and 6, almost as far as outer margin; all the veins somewhat infuscate; discocellular dot faint; terminal dots as on upperside; of hind wing whitish tinged with pale pinkish buff. Expanse 30 mm.

The frons is convex, slightly projecting, with a rounded protuberance at the apex (fig. 3, *q*).

French Guiana: St. Jean du Maroni, 2 ♀♀.

Holotype ♀, and paratype ♀, in Tring Museum.

The British Museum has one female, very much faded, labelled "Venezuela (*W. Schaus*)."

A medium-sized species, quite unlike any other at present known in the genus. The genitalia suggest a relationship with *pedibarbata*.

27. Diatraea albicrinella, sp. nov. (Pl. i, figs. 5, 6; Pl. v, fig. 15).

♂. Palpus light buff tinged with vinaceous buff, streaked with avellaneous to wood-brown. Antennal shaft honey-yellow with sparse warm buff scales. Head light buff or pinkish buff tinged with cinnamon-buff; a darker median line sometimes present on vertex. Thorax pinkish buff to cinnamon-buff tinged with cinnamon, sometimes strongly tinged with ochraceous tawny. Tergum warm buff, sometimes slightly infuscate, proximal two segments cinnamon-buff to cinnamon, anal segments cartridge-buff to light buff. Pectus light buff tinged with warm buff. Legs the same; posterior tibia with a large conspicuous tuft of whitish to light pinkish buff scales on inner margin. Venter cartridge-buff to pinkish buff. Fore wing with ground-colour light buff tinged with warm buff, or warm buff tinged with cinnamon-buff, faintly tinged with snuff-brown on a triangular patch below costa at apex, and interneurally on outer margin, rather strongly so on a broad streak on inner margin below vein 1c; the veins lined with cinnamon to snuff-brown; a fuscous blackish discocellular dot; two oblique wavy fuscous brownish lines, wider and darker basad than apicad, the first from the dark apical shade in a wide curve (concavity basad) around and below the cell to base of vein 2, then rather abruptly bent downwards and inwards to run into inner margin at a point one-third its length from base; the second, sometimes resolved into separate rounded dots on the veins, but more often irregularly denticulate, from vein 10 near apex in a wide curve to inner margin just beyond middle, merging into the dark shade here; a terminal series of fuscous blackish interneural dots. Hind wing whitish tinged with pale pinkish buff, tinged with pinkish buff on costa, and on a narrow terminal line on outer margin; distinct traces of fuscous terminal dots (sometimes coalescing) on outer margin below apex. Underside of fore wing pinkish buff tinged with cinnamon-buff, tinged with cinnamon on veins and along costa; discocellular and terminal dots indistinct; of hind wing whitish tinged with pale pinkish buff, especially on costa; faint traces of terminal dots on outer margin near apex. Expanse 26–33 mm.

♀. Similar, larger, colouring generally similar to and equally intense as that of the ♂. Palpus, head and thorax more often predominantly light drab or light cinnamon-drab. Tergum often strongly infuscate. Hind tibia without tuft of hair-like scales. Expanse 32–45 mm.

The frons is gently convex to bulging, with a rounded protuberance at the apex (fig. 3, *r*).

15 ♂♂, 20 ♀♀ (B.M., T.M., U.S.N.M., Z.M.U.B.) :—BRITISH GUIANA: Potaro, i, ii & v.1908 (*S. M. Klages*). BRAZIL (AMAZONS): Massanary (*Dognin coll.*); R. Jutahi, 5.ii.1875; Fonte Boa, v & vii.1906 (*Klages*) (holotype ♂ and allotype ♀); Teffe, i.1905 (*M. de Marthan*); Pebas, 1896–97 (*Michael*). PERU: Callanga, Prov. Cuzco, 1,500 ft. (*O. Garlepp*); Vilcanota, Prov. Cuzco, 3,000 ft. (*Garlepp*); Marcapata, 4,500 ft.; Caradoc, Marcapata, 4,000 ft., ii.1901 (*G. Ockendon*); La Oroya, Rio Inambari, 3,100 ft., iii.1905 (wet season) (*Ockendon*); Tinguri, Carabaya, 3,400 ft., viii.1904 (dry season) (*Ockendon*). ECUADOR: Rio Verde, Rio Pastaza, 5,000 ft. (*M. G. Palmer*); El Rosario, Rio Pastaza, 4,900 ft. (*Palmer*); "Loja—Equateur," 1893 (*Dognin coll.*).

Holotype ♂ in Tring Museum.

A female in the Tring Museum, doubtfully referable here, is uniformly more greyish than brownish in colour; it is labelled "BRAZIL: Anhangahy, São Paulo, xii.1926 (*E. Spitz*)."

D. albicrinella is a large, rather broad-winged species with characteristic colour and markings, readily recognisable by the genitalia of both sexes; the large tuft of whitish hair-like scales on the hind tibia of the male render this sex unmistakable.

28. Diatraea amnemonella, Dyar (Pl. v, fig. 3).

Diatraea amnemonella, Dyar, Ent. News, xxii, 1911, p. 203; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 21, ff. 14, 62.

A medium-sized, narrow-winged form suggestive of a dark-coloured *Crambus.*

A single female is in the British Museum, from Brazil, labelled " Castro, Parana, 950 m. (*E. D. Jones*)." The identification has been confirmed by Dr. Heinrich, who kindly compared this specimen with the type material from the same locality. The shape of the frons is shown in fig. 4, *a*.

Additional remarks on this species appear in the discussion of *D. castrensis*, below.

29. Diatraea castrensis, Dyar & Heinr.

Diatraea castrensis, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 28, f. 25.

Unknown to the writer. Known only by the unique male type in the U.S. National Museum, from Castro, Parana, Brazil.

Dyar & Heinrich state that this species is " Very similar to *amnemonella*; the colour a little less brown, though still distinctly brown tinted," but *amnemonella* is said by Dyar, in his original description, to be " Similar to *canella*, Hamps. . . . The female is grey, like the male . . .," and by Dyar & Heinrich to have the " fore wing reddish grey, sparsely black irrorate, forming traces of cross lines."

A female in the British Museum, determined by Dr. Heinrich as *D. amenmonella*, has the fore wing vinaceous buff irrorated with wood-brown to produce an avellaneous tint; the cell and a streak beyond to outer margin between veins 5 and 6 vinaceous buff; a warm buff line in cell from base to apex. The genitalia do not quite agree with the description and figure published by Dyar & Heinrich, and the writer was inclined to believe at one time that this was the hitherto unknown female of *castrensis*.

The male genitalia of *amnemonella* suggest a relationship with *canella*, Hamps., but those of *castrensis* are quite different and are closest to *cayenella*, according to the figures of these organs published by Dyar & Heinrich. Another instance in which two species apparently closely related have quite distinct types of genitalia.

30. Diatraea canella, Hamps. (Pl. v, fig. 7).

Diatraea canella, Hampson, Ann. Mag. N. H.,(6) xvi, 1895, p. 349; Proc. Zool. Soc. Lond., 1895, p. 954; Dyar, Ent. News, xxii, 1911, p. 202; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 20, ff. 13, 60.

Phalaena sacchari, Sepp, Surinamsche Vlinders n. h. Leven geteekend, ii, 1848, p. 135, pl. 64 (nec *Crambus sacchari*, Fabr., Suppl. Ent. Syst., 1798, p. 469, no. 31, = *D. saccharalis*, Fabr.; nec *Diatraea sacchari*, Guild., Trans. Soc. Encour. Arts, etc., xlvi, 1828, p. 149, = *D. saccharalis*, Fabr.).

A medium-sized, distinctively coloured and well-marked species occurring in the Guianas, Venezuela and certain of the West Indian islands as an important pest of sugar-cane. The characteristic frons is shown in fig. 4, *b*.

In the publication of Sepp, cited above, a description of the habits and life-history of the insect is given which might refer to other species of *Diatraea*, but his coloured figures of the adult indicate that this was the species to which he referred. His name cannot be used, however, as *Diatraea sacchari* is already occupied (Guilding, 1828).

No detailed account of the bionomics of *D. canella* has yet been published, but reference to its habits and economic status as a sugar-cane pest in British Guiana

have been made by Cleare (Bull. Ent. Res., xiii, 1922–23, p. 457 *et seq.*) and Box (*op. cit.*, xvi, 1925–26, p. 249 *et seq.*). Cleare gives useful descriptive notes of the egg and larva of this species.

According to Hampson, *canella* is found in Brazil, but the writer has not seen any Brazilian specimens among the very considerable series in the British Museum. Dyar states that " Brazilian specimens before me are separable specifically," and describes them under the name *amnemonella* (p. 35).

The reference of Van Zwaluwenburg to the occurrence of *D. canella* as a sugar-cane pest in Mexico (J. Econ. Ent., xix, 1926, p. 664) is unquestionably an error ; it is most probable that *D. magnifactella* is the species there concerned.

According to Dyar & Heinrich, *D. anathericola* (p. 38) has genitalia which in both sexes are " as in *canella* " ; the general appearance of this moth is, however, quite different, the shape of the fore wing giving it a decided crambiform appearance. *D. amnemonella*, which is also crambiform, has genitalia of the *canella* type, but they can be definitely recognised as distinct. Two other species, *amazonica*, sp. n., and *rufescens*, sp. n., are clearly more closely related to *canella* than either of the above on external characters and to some extent on the structure of the genitalia.

88 ♂♂, 63 ♀♀ (B.M., I.I.E., T.M., O.M.) :—GRENADA : St. Andrew's, 170 ft., iv.1890 ; Mount Gay Estate (*H. H. Smith*) ; Balthazar (*Smith*). TOBAGO : Cocoa Wattie, 8.iv.1907 (*G. B. Longstaff*). TRINIDAD : reared from larvae in sugar-cane, various dates i–ii.1929 (*J. G. Myers*) ; reared from known females, larvae fed on maize, xi.1929–iv.1930 (*F. W. Urich*) ; Port of Spain, xii.1896–ii.1897 (*Rendall*) ; Port of Spain (*F. Birch*) ; St. Augustine, 3.ix.1924 (*C. L. Withycombe*) ; Caparo, xi–xii.1905 (*S. M. Klages*). VENEZUELA : Carúpano, xii.1891 (*C. W. Ellacombe*) ; Suapure (*S. M. Klages*) ; La Victoria, reared from larvae in sugar-cane, x.1929 (*H. T. Osborn*). BRITISH GUIANA : (*J. Rodway*) ; Rockstone (*W. J. Kaye*) ; Bartica, iii–iv.1901 (*Kaye*). DUTCH GUIANA : Paramaribo, xi.1892 (*C. W. Ellacombe*) ; Berg en Daal, iii.1892 (*Ellacombe*). FRENCH GUIANA : St. Laurent du Maroni ; St. Jean du Maroni.

31. Diatraea amazonica, sp. nov. (Pl. i, figs. 1, 2 ; Pl. iv, figs. 4, 5).

♂. Palpus light buff to pinkish buff, tinged with warm buff to cinnamon-buff at sides and at apex. Antennal shaft dark brownish with sparse light buff or pinkish buff scales. Head cream-colour above, light buff to warm buff at sides. Thorax warm buff tinged with some ochraceous buff, especially at sides. Tergum light buff, proximal two segments ochraceous tawny, anal segment cartridge-buff. Pectus pale pinkish buff tinged with warm buff. Legs the same. Venter cartridge-buff tinged with pinkish buff. Fore wing pinkish buff tinged with warm buff to ochraceous buff, especially on costa, outer margin and apical half of inner margin ; an area at apex of cell and a streak beyond to outer margin between veins 5 and 6, whitish to pale pinkish buff ; the entire surface sparsely irrorated with scattered fuscous-tipped scales which tend to form lines interneurally ; a small indefinite triangular fuscous patch below costa at apex ; a fuscous blackish discocellular dot ; two oblique fuscous lines, the first composed of short narrow streaks on and between the veins from apex of cell at base of vein 10, in a wide curve around and below the cell to vein 5 at base, then broadening slightly below middle of cell and bending to run into inner margin near base ; the second a series of round dots on the veins, from 7 vein at middle outwards to vein 6 near apex, then in a gentle curve (concavity basad) to inner margin at middle ; a terminal series of fuscous interneural dots. Hind wing whitish tinged with pale pinkish buff, tinged with light buff on costa and outer margin at apex. Underside of fore wing avellaneous to wood-brown except on costa, outer margin, inner margin below vein 1c, the cell, and a streak beyond, between veins 5 and 6, where it is light buff tinged with warm buff ; the veins slightly

infuscate ; discocellular and terminal dots faint ; of hind wing whitish tinged with cartridge-buff to light buff, tinged with some warm buff on costa and outer margin at apex. Expanse 28 mm.

♀. Variable.* The allotype and two paratypes are similar to the ♂, but larger, with the coloration somewhat lighter and the markings of the fore wing less distinct ; they are very similar to the ♀ of *canella*, but without the pinkish tinge characteristic of that species. Expanse 36 mm. Two other paratypes are larger, the fore wing darker (light ochraceous buff), with the discocellular dot very large (almost 1 mm. in diameter) ; one of these specimens has the oblique lines well defined and contrasted, the first line being rather short, from vein 6 at base in a curve around and below the cell to vein 2 at middle, not continuing to the inner margin, the second line being as in the ♂, but consisting of small crescent-shaped marks between the veins, rather than round dots on the veins ; the second of these specimens has similar but less distinct markings. Expanse 38 mm.

The frons is prominent, triangularly produced with the sides roundly tapering to a sharp point at the apex (fig. 4, *c*).

2 ♂♂, 5 ♀♀ (B.M., T.M., U.S.N.M.) :—BRAZIL (R. MADEIRA) : Calama (*W. Hoffmanns*) (holotype ♂, allotype ♀) ; Allianca, below San Antonio, xi–xii.1907 (*Hoffmanns*) ; W. bank about 5° 30′ S., 16.v.1874. ARGENTINA : Villa Ana, Santa Fé, i.1924 (*K. J. Hayward*).

Holotype ♂ in Tring Museum.

A rather large species, closely related to *canella*, Hamps., and *rufescens*, sp. n., but without any pinkish tinge to the fore wing. The female genitalia are very distinct and unlike anything yet seen in *Diatraea*, but in the male careful examination is needed to avoid confusion with the two species mentioned above ; characters of specific value will be found in the shape of the vinculum and of the sub-basal digitate projection from the costa of the harpes, and particularly in the spining of the lateral arms of the anellus.

32. Diatraea rufescens, sp. nov. (Pl. i, figs. 3, 4 ; Pl. iv, fig. 6 (?)).

♂. Palpus vinaceous buff streaked with vinaceous fawn. Antennal shaft dark brownish with sparse pinkish buff scales. Head pale pinkish cinnamon tinged with vinaceous buff with some avellaneous at sides. Thorax vinaceous buff tinged with vinaceous fawn at sides and in front. Tergum pinkish buff tinged with "greyish," proximal two segments cinnamon-buff. Pectus pinkish buff. Legs the same. Venter cartridge buff tinged with pinkish buff. Fore wing with markings exactly as in *amazonica*, sp. n. (p. 36), but the general colour is vinaceous buff tinged with vinaceous fawn, especially on costa, outer margin and apical half of inner margin. Hind wing whitish tinged with pale pinkish buff, tinged with vinaceous buff to vinaceous fawn on costa and outer margin at apex. Underside of both wings as in *amazonica*. Expanse 28 mm.

The frons is the same as in *amazonica* (fig. 4, *c*).

BOLIVIA : Buenavista, 750 m., viii.1906–iv.1907, 1 ♂ (*J. Steinbach*).

Holotype in Tring Museum.

A female, from Bolivia, much faded and in very poor condition, may belong here. In size and coloration it agrees with the above description, but the discocellular dot is very large (about 0·75 mm. in diameter) (*cf. amazonica*, ♀). The genitalia (Pl. iv, fig. 6) are like those of *D. canella*, Hamps., to which species Dr. Heinrich thinks this

* The five females (allotype and four paratypes) are associated together by the similarity of their genitalia, which leaves no room for doubt that they are conspecific. The pattern of the fore wing is so variable among certain of them that one might easily be led to believe two distinct species to be represented.

specimen may possibly belong. It is in the Tring Museum and labelled "Prov. Sara, Dept. Santa Cruz de la Sierra, end ii. to vi.1904 (*J. Steinbach*)."

D. rufescens belongs to the same group as *canella* and *amazonica*, and the male genitalia of all three are of similar construction. The shape of the vinculum and the type of spining of the lateral arms of the anellus, however, render *rufescens* quite distinctive.

33. Diatraea anathericola, Dyar & Heinr.

Diatraea anathericola, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 21.

Unknown to the writer. Known by the male type in the U.S. National Museum, from São Paulo, Brazil, and two females from British Guiana (bred from larvae found boring in the stems of *Anatherium bicorne*) in the same institution.

This species, *strigipennella* and *cayenella*, are stated by Dyar & Heinrich to be superficially indistinguishable from one another, and to be separable only on the genitalia. The genitalia of *anathericola* are "(male and female) as in *canella*," but those of the other two species named are different in every respect.

The writer has been able to detect certain differences which may be of value for separating *strigipennella* and *cayenella*, particularly in the presence of oblique rows of dots on the fore wing of the latter, which are absent in the former. The description of *anathericola* would seem to indicate that the species resembles *strigipennella* in the above respect.

34. Diatraea strigipennella, Dyar (Pl. iv, fig. 1).

Diatraea strigipennella, Dyar, Ent. News, xxii, 1911, p. 206; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 27, ff. 23, 66.

The British Museum has four females from Brazil, labelled "Castro, Parana, 950 m. (*E. D. Jones*)." They are similar to one another in size (expanse 26 mm.) and in coloration. Dyar & Heinrich state that this species is "indistinguishable in coloration or frontal structure from *anathericola*," and that *cayenella*, in its turn, is "indistinguishable from *strigipennella* and *anathericola*. . . ." The present writer has not seen *anathericola*, but has before him, in addition to the four females of *strigipennella*, five females the genitalia of which agree with the description and figure of *cayenella* presented by Dyar & Heinrich. Whilst admitting the extraordinary similarity in the general aspect of our *strigipennella* to *some* of our examples of *cayenella*, it is noticeable that in the former no trace of cross-lines or dots on the veins of the fore wing can be detected, whereas such can be found in all five specimens of *cayenella*, admittedly very faint and indistinct in three of them, but nevertheless observable, and very pronounced in one specimen. Also, it would appear that the top of the frons, when viewed laterally, is more convex in *strigipennella* (fig. 4, *d*) than in *cayenella*, in which the top is almost flat (fig. 4, *e*). The writer does not feel justified, however, in insisting that these are good specific characters, owing to the small number of specimens examined, and the fact that he has not seen the male of either species concerned.

Very closely related to the present species is *entreriana*, sp. n. (Argentina).

35. Diatraea cayenella, Dyar & Heinr. (Pl. v, figs. 10, 11).

Diatraea cayenella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 27, ff. 24, 65.

This species has already been partly discussed under *strigipennella*. According to the original description, it would seem impossible to separate *cayenella* from either *anathericola* or *strigipennella* except on the genitalia.

The five specimens of *cayenella* vary considerably in size (expanse: 26, 26, 30, 31, 36 mm.) and coloration. With the exception of one specimen, all have the ground-colour of the fore wing whitish to pale pinkish buff, with the veins and interneural lines contrasting in avellaneous to vinaceous fawn, with a conspicuous whitish streak from the cell to outer margin between veins 5 and 6; the other specimen has a ground-colour of avellaneous to wood-brown, with the veins and interneural lines very faintly contrasting, and the light streak is subordinated. All of them, however, agree with *cayenella* in their genitalia.

5 ♀♀ (B.M., T.M.):—BRAZIL: Castro, Parana, 950 m. (*E. D. Jones*); São Paulo; Santos.

36. Diatraea entreriana, sp. nov. (Pl. i, figs. 11, 12, 13; Pl. iv, fig. 2).

♂, ♀. Palpus whitish or pale pinkish buff, sometimes streaked with vinaceous buff to wood-brown. Antennal shaft honey-yellow finely clothed with whitish to pinkish buff scales. Head whitish or pale pinkish buff, tinged with pinkish buff; a slightly darker (avellaneous) median line sometimes present on vertex. Thorax whitish to pinkish buff, sometimes tinged with vinaceous buff to avellaneous at sides. Tergum pinkish buff, proximal two segments cinnamon-buff. Pectus pale pinkish buff. Legs the same. Venter whitish tinged with cartridge-buff. Fore wing generally whitish, cartridge-buff or pale pinkish buff, tinged with cinnamon-buff to cinnamon on costa and outer margin, the surface sparsely irrorated with scattered individual fuscous-tipped scales which tend to form lines interneurally; a fuscous blackish discocellular dot; all the veins with contrasting lines of warm buff to cinnamon-buff scales; similar but lighter (ochraceous buff) lines of scales in the interneural spaces apically, subordinated where the fuscous irroration is present; a light (cartridge-buff to pinkish buff) from middle of cell to outer margin between veins 5 and 6 (sometimes not continuing beyond apex of cell), a terminal series of fuscous blackish interneural dots; there are no traces of transverse oblique lines or dots on the wing. Hind wing uniformly whitish. Underside of fore wing cartridge-buff, tinged with pinkish buff on costa and outer margin, sometimes darker (light buff tinged with cinnamon-buff); a light streak from middle of cell to outer margin between veins 5 and 6; discocellular and terminal dots faint or obsolete; of hind wing uniformly whitish slightly tinged with pale pinkish buff. Expanse, ♂♂—19–21 mm., ♀♀—17·5–26 mm.

The frons is slightly protuberant, convex, with a sharp point at the apex; viewed laterally, the top of the frons is rather strongly convex (fig. 4, *f*).

ARGENTINA: La Soledad, Entre Rios, close to frontier of Uruguay, 1 ♂, 29.i.1905 (holotype), 1 ♀, 26.ii.1905 (*Miss E. A. Britton*); La Soledad, 4 ♂♂, 50 ♀♀, 1898–1909 (*Britton*).

Holotype ♂ in Tring Museum, paratypes in B.M., T.M., U.S.N.M.

Three other females, excluded from the paratype series, but with similar data, have vein 10 stalked with 8+9 for some distance in the fore wing (fig. 5, D); the types and 54 paratypes have vein 10 free from the cell (fig. 5, A).

Except for its uniformly smaller size and the absence of any pinkish (vinaceous) tinge to the general colour of the fore wing, and the fact that the veins and the light streak from cell to outer margin are much less contrasting, this form agrees externally with *strigipennella*. All the essential features of the very peculiar genitalia of *strigipennella*, as described and illustrated by Dyar & Heinrich, are present in *entreriana*, but differences can be detected in both sexes, notably in the shape of the vinculum and of the curious sub-basal projection from the harpe, in the male, and in the sculpture of the chitinized area below the genital opening and the form of the "internal, median girdle of serrate ridges" in the bursa, in the female.

D. entreriana might easily be mistaken for a small light-coloured *Crambus*.

37. Diatraea guapilella, Schs.

Diatraerupa guapilella, Schaus, Ann. Mag. N.H., (8) xi, 1913, p. 240; Proc. Ent. Soc. Wash., xxiv, 1922, p. 137.

Iesta guapilella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 5.

Unknown to the writer. Known only by the unique female type in the U.S. National Museum, from Guapiles, Costa Rica.

Reference to this form has been made in the discussion of *morobe*, Dyar (p. 19), which, according to Dyar and Heinrich, "may prove to be a varietal form of *guapilella* with which it agrees in genitalia." Both of these species were hitherto known only in the female sex, and the genitalia of *morobe* are figured by the authors named; the genitalia of *guapilella* are not figured but are stated to be "similar to those of *lisetta* except for a stronger chitinization of the ductus and neck of bursa"; the female genitalia of *lisetta* (an entirely different insect) are illustrated, and seem to have little in common with those of *morobe*, so that on the evidence presented by Dyar & Heinrich themselves it is almost certain that *guapilella* is a distinct and valid species.

38. Diatraea venosalis, Dyar.

Haimbachia venosalis, Dyar, Insec. Insc. Mens., v, 1917, p. 87; Forbes, J. N.Y. Ent. Soc., xxviii, 1920, p. 221.

Diatraea venosalis (Dyar), Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 22, ff. 16, 58.

A single male, in the Tring Museum, labelled "Texas," agrees with the description of this species; the genitalia were not examined as the abdomen is missing, but there is very little doubt attached to the determination.

The only specimens hitherto known are 4 ♂♂ and 1 ♀ in the U.S. National Museum, from Audubon Park, Louisiana, U.S.A.

39. Diatraea evanescens, Dyar.

Diatraea evanescens, Dyar, Insec. Insc. Mens., v, 1917, p. 84; Forbes, J. N.Y. Ent. Soc., xxviii, 1920, p. 224; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 18, ff. 10, 57.

Diatraea sobrinalis, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 140; Dyar & Heinrich, *loc. cit.*

The British Museum has one female, very much faded and generally in poor condition, which is placed here on the evidence of the genitalia; it is labelled "GUATEMALA: Quirigua (Schaus & Barnes Coll.)." Another female, also in bad condition, labelled "Limas, Norris Coll." (B.M.), may also belong here.

Dyar & Heinrich cite this species from Audubon Park, Louisiana, U.S.A., and Cayuga, Guatemala, and state that the food-plant of the larva is *Paspalum larranagae*.

40. Diatraea angustella, Dyar (Pl. iii, fig. 4).

Diatraea angustella, Dyar, Ent. News, xxii, 1911, p. 205; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 17, ff. 8, 56.

Some observations on this species are given below, in the discussion on *D. impersonatella*, Walker.

In regard to the specimens listed as belonging to *angustella* the following notes are pertinent:—

All of those from the type locality—Castro, Brazil—are uniformly dark coloured; the pattern of the fore wing is formed of lines on and between the veins of various shades of brown on a lighter (ochraceous buff) ground-colour; the males are much

darker than the females and have the veins more strongly contrasting in lines of cinnamon-brown with broad tawny olive lines between the principal veins; these colours appear in the female, but not so sharply defined; in both sexes the frons, seen from above, is uniformly smooth and rounded (fig. 3, *f*), somewhat as in *saccharalis*.

Two females, from Anhangahy and Castro, respectively, have the fore wing more greyish (light pinkish cinnamon, tinged with avellaneous or cinnamon-buff) than brownish; the genitalia seem to be intermediate between typical *angustella* and the species we know as *impersonatella*. The first of these specimens has the frons smooth and rounded (fig. 3, *f*), and in the second the frons has a sharp point at the apex (fig. 4, *g*).

The female from Paraguay, and all the Argentine females, included as doubtful, are much lighter in colour (pinkish buff to warm buff, slightly tinged with cinnamon-buff) than the Brazilian specimens, but agree with typical *angustella* in genitalia; some of them have the frons smooth and rounded, others have a small point at the apex.

The two males, from widely separated points in Argentina, are small (expanse 23 mm., compared with 27–30 mm. of typical males from Castro) and very light coloured, the fore wing having the ground-colour almost whitish, with the veins and interneural lines contrasting in wood-brown and avellaneous, respectively; in these two specimens the frons is the same as in typical *angustella*, for which reason they are included here.

There is no reason to believe that any of the above represent distinct species, though it is possible that they may be variants of *impersonatella*. If, however, they are correctly determined as *angustella*, this species must be recognised as being variable in coloration and frontal structure to a degree greater than is usual in the genus.

As noted by Dyar & Heinrich, no constant specific characters can be found in the male genitalia for the separation of *angustella* and *impersonatella*, though the female genitalia of *typical* specimens of each form are quite distinctive, and are correlated with the coloration of the fore wing and the frontal structure. Attention has been drawn, however, to the fact that in non-typical specimens these various characters seem to overlap, with the result that several specimens cannot be determined with any reasonable degree of accuracy.

These facts tend to indicate that *angustella* and *impersonatella* may eventually be found to be but the extremes of one and the same species.

5 ♂♂, 9 ♀♀ (B.M., T.M.):—BRAZIL: Anhangahy, São Paulo, xii.1926 (*E. Spitz*); Castro, Parana, 950 m. (*E. D. Jones*).

Doubtful specimens—3 ♂♂, 10 ♀♀ (B.M., T.M.):—BRAZIL: Iguassu, Parana, 5.iii.1922. PARAGUAY: Sapucay, 20.i.1904 (*W. Foster*). ARGENTINA: Villa Ana, Santa Fé, i, ii & xii.1924 (*K. J. Hayward*); Rosario, Santa Fé, xii.1898 (*Stuart*); near Florenzia, Gran Chaco, x & xii.1902 (*S. R. Wagner*).

41. Diatraea impersonatella, Walk. (Pl. iii, figs. 2, 3).

Crambus impersonatellus, Walker,* List Lep. Ins. Brit. Mus., xxvii, 1863, p. 163.
Diatraea moorella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 17.

Walker described both sexes from a series, of which "*a—e*" came from Venezuela, and "*f, g*" from Santarem. The only specimen which we can to-day assert to

* *Crambus impersonatellus*, Walk., was erroneously considered a synonym of *Diatraea lineolata*, Walk., by Hampson (Proc. Zool. Soc. Lond., 1895, p. 953), who has been followed by all authors who have discussed the synonymy of *D. lineolata* since that date.

have been included among the above, is the female type in the British Museum, from Venezuela. The genitalia have been examined, and the specimen agrees in every way with the form described as *Diatraea moorella*, Dyar & Heinrich, from British Guiana, paratypes of which have been seen by the writer.

This moth shows a very close affinity to *angustella*, Dyar, but can be distinguished from typical specimens of the latter by the lighter colour of the fore wing (♂, cinnamon-buff, veins and interneural lines strongly contrasting in snuff-brown and tawny olive, respectively ; ♀, pinkish buff to warm buff, lines less contrasting) and the presence of a sharp point at the apex of the frons (fig. 4, *h*).

The larva of *D. impersonatella* has been known for many years as a sugar-cane borer of minor importance in British Guiana and Trinidad ; in each case, however, where reference has been made to this insect in the countries named, it has been under the erroneous determination of " *Diatraea lineolata*." Cleare's description of the larva (Bull. Ent. Res., xiii, 1922–23, p. 458) of " *lineolata* " agrees with specimens seen by the writer, which were found in sugar-cane in Trinidad by Dr. J. G. Myers and definitely associated with adults since determined as *impersonatella*. Dr. Myers has found that in certain parts of Trinidad this species is the predominant borer in sugar-cane, which suffers considerable damage in consequence ; there is some evidence that *impersonatella* does not occur in the northern part of that island, or, if so, but rarely. In British Guiana it is never so abundant as either *saccharalis* or *canella*.

26 ♂♂, 29 ♀♀ (B.M., T.M., O.M., I.I.E., Z.M.U.B.) :—TRINIDAD : (*Dyer*) ; reared from larvae in sugar-cane, various dates, i–ii. 1929 (*J. G. Myers*). BRITISH GUIANA : Berbice (*J. Aiken*). DUTCH GUIANA : Onoribo, ii. 1893 (*C. W. Ellacombe*). BRAZIL : (*Lotzky*) ; (*Miers Coll.**) ; Rio de Janeiro.

Through the kindness of Dr. Heinrich, the writer has been able to examine two paratypes, ♂ and ♀, of *D. moorella*, lent by the U.S. National Museum ; these were reared from larvae in *Anatherium bicorne* by Mr. H. W. B. Moore in British Guiana. Another paratype ♀, from Castro, Brazil, sent with the above, is distinct, and is here included in the series of *flavipennella*, sp. n.

Doubtful specimens—3 ♂♂, 3 ♀♀ (B.M., T.M.) :—ARGENTINA : Goya, Prov. Corrientes (*Perrins*) ; nr. Florenzia, Gran Chaco, x & xii.1902 (*S. R. Wagner*). BOLIVIA : Sarampioni, 800 m., viii.1901 (dry season) (*Simons*).

42. Diatraea flavipennella, sp. nov. (Pl. i, figs. 9, 10 ; Pl. v, fig. 6).

♂. Palpus light buff streaked with wood-brown at sides and below. Antennal shaft brownish, finely clothed with light buff scales. Head cartridge-buff to light buff, tinged with some vinaceous buff. Thorax light buff tinged with ochraceous buff, especially in front and at sides. Tergum cartridge-buff tinged with light buff, proximal two segments ochraceous tawny. Pectus light buff. Legs cartridge-buff to light buff, tinged with some warm buff. Venter cartridge-buff. Fore wing light buff to light ochraceous buff, tinged with warm buff on costa, especially at base ; a fuscous blackish discocellular dot ; all the veins with contrasting lines of cinnamon to snuff-brown scales, those on the median area noticeably darker ; the cell and interneural spaces, except between veins 5 and 6, with similar, but lighter lines of scales ; a distinct light buff streak from cell to outer margin between veins 5 and 6, upon which a faint yellowish line can be just detected ; a terminal series of fuscous terminal interneural dots. Hind wing light buff tinged with sordid whitish,

* Professor Poulton informs me that Miers made his collections in the vicinity of Rio de Janeiro.—H. E. B.

tinged with some warm buff on costa and outer margin at apex ; the veins above vein 6 with traces of lines of light buff scales ; faint traces of fuscous terminal dots on outer margin below apex. Underside of fore wing light buff tinged with wood-brown, tinged with cinnamon-buff on costa ; the veins with slightly darker lines of scales a distinct light buff streak from apex of cell to outer margin between veins 5 and 6 of hind wing light buff tinged with warm buff, tinged with some wood-brown on costa. Expanse 30 mm.

♀. Similar in size and general aspect. Hind wing more whitish, but tinged with some light buff on costa. Underside of both wings much lighter than in the ♂, without any wood-brown tinge. Expanse 30 mm.

The frons is smooth and rounded, somewhat bulging, without a point at the apex (fig. 3, *e*).

1 ♂, 5 ♀♀ :—BRAZIL : Castro, Parana, 950 m. (*E. D. Jones*) (holotype ♂) ; Salto Grande, Paranapanema (*E. D. Jones*).

Holotype ♂ in British Museum ; paratypes also in U.S.N.M. The single paratype ♀ in the U.S. Nat. Mus., from Castro, was originally paratype no. 29429 of *Diatraea moorella*, Dyar & Heinr.

A narrow-winged yellowish form which, judging by the genitalia, is related to *angustella* and *impersonatella*, but differing in the shape of the fore wing, in which the angle formed by the costa and outer margin is very acute ; from *impersonatella*, which is also a yellowish species, *flavipennella* can be separated by the frontal structure, and its general aspect is decidedly crambiform. Whereas in both of the other species named the two sexes are readily recognisable by the coloration of the fore wing, the males having the veins and interneural lines contrasting to a greater degree than the females, in *flavipennella* the sexes are similar to one another in the coloration of the fore wing ; the relatively dark hind wing of the male also makes this species rather distinctive.

43. Diatraea busckella, Dyar & Heinr. (Pl. iii, fig. 5).

Diatraea busckella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 16, ff. 5, 53.

Hitherto known only by the male and female types in the U.S. National Museum, from Porto Bello, Panama.

In the original description, the fore wing is said to be " light yellowish straw colour, paler in the female than in the male ; veins conspicuously lined in brown " ; the genitalia of both sexes are figured, but the descriptions of these organs given by the authors are a better aid to identification, for which reason the genitalia of the female are again illustrated in the present paper. All of the specimens before the writer have the fore wing of a most distinctive colour, not seen elsewhere in *Diatraea*, viz., capucine buff to light ochraceous salmon, tinged with pinkish cinnamon, the sexes being similar in this respect ; the veins are lined with pinkish cinnamon to cinnamon ; the interneural lines are somewhat lighter ; the veins and interneural lines are much less contrasting in the female than in the male. The frons is shown in fig. 4, *i*, but in some examples the apex is more sharply pointed (*cf.* fig. 3, *j*).

D. busckella appears to be widely distributed in Venezuela wherever sugar-cane is grown, and in certain localities its larvae are the predominant species of borer present, even where *saccharalis* and *canella* also occur in the same fields. The writer's original notes on the larva are unfortunately lost, but it is hoped that material will be forthcoming shortly upon which a description can be based.

8 ♂♂, 15 ♀♀ (B.M., T.M., Z.M.U.B.) :—COLOMBIA : (*Moritz*). VENEZUELA : Valencia ; reared from larvae in sugar-cane, as follows : Caracas Valley, vii.1926 (*H. E. Box*) ; Haciendas Tarapio and Tacarigua, near Lago Valencia, ii–iii.1927 (*Box*) ; Hacienda Paya, Carabobo, xii.1929 (*H. T. Osborn*).

44. Diatraea grandiosella, Dyar (Pl. v, fig. 16).

Diatraea grandiosella, Dyar, Ent. News, xxii, 1911, p. 205 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 25, ff. 21, 68.

Diatraea lineolata (Walker), Barnes & McDunnough, Check List Lep. Bor. Amer., 1917, p. 141 (nec *Leucania lineolata*, Walk., List Lep. Ins. Brit. Mus., ix, 1856, p. 100 = *Diatraea lineolata*, Walk.).

Described originally from Guadalajara, Mexico. Dyar remarks that the " single large female differs from the series of *lineolata* in its brownish colour ; without any yellow tint." Dyar & Heinrich refer to *grandiosella* as " a rather large, light coloured species. Fore wing pale, whitish, with slight yellow tint. . . ." This discrepancy requires explanation.

The considerable series before the writer includes several very large specimens from Guadalajara (expanse, 2 ♂♂, 32–36 mm. ; 4 ♀♀, 39–45 mm.), in which the fore wing has the veins and interneural lines strongly contrasting in ochraceous buff to pinkish cinnamon ; discocellular dot distinct, blackish. Other examples, from Arizona and New Mexico, and also one from Guadalajara, Mexico, are much smaller (expanse, ♂♂, 25–30 mm. ; ♀♀, 30–37 mm.), with the fore wing almost uniformly light buff tinged with pinkish buff, without contrasting lines on and between the veins ; discocellular dot obsolete. Specimens intermediate in coloration have been seen, so that it does not appear justifiable to recognise subspecies, though the extremes are so very different as to appear specifically distinct. Dyar & Heinrich state " Front without a tubercle." Among the specimens examined, all have the frons smooth and rounded, and rather strongly bulging (fig. 2, A–B), but in some of them there is a definite rounded protuberance at the apex (fig. 4, *j*) ; this variation is not correlated in any way with the colour-forms noted above. No variation in the structure of the genitalia has been noted.

D. grandiosella is limited in its distribution to a wide belt extending northwards from western central Mexico to the United States, whence records (generally under the erroneous determination of *D. lineolata*) are forthcoming from Southern California, New Mexico, Arizona and the western part of Texas. A valuable contribution to our knowledge of this insect, which is known as the " Southwestern Corn Borer " (not to be confused with the " Larger Corn-stalk Borer," *D. crambidoides*, Grote), has recently been published by C. J. Todd & F. L. Thomas (J. Econ. Ent., xxiii, 1930, p. 118) ; these authors give the following brief abstract of their observations : " The southwestern corn borer has been gradually spreading from Mexico, until now it has reached the northern border and is halfway across the Panhandle of Northwest Texas. It has been causing considerable injury to corn and has been found infesting several grain sorghums." From the dates on the specimens examined by the present writer, and from the records in literature, it would seem that *D. grandiosella* has been established in the United States for many years. According to Urich (J. Econ. Ent., vi. 1913, p. 248) this species attacks sugar-cane in Mexico, and it is possible that Van Zwaluwenburg's references to *D. lineolata* (J. Econ. Ent., xvi, 1923, p. 227 ; *op. cit.*, xix, 1926, p. 664) as an important enemy of sugar-cane in the state of Sinaloa, Mexico, also apply to *grandiosella*.

11 ♂♂, 20 ♀♀ (B.M., T.M.) :—U.S.A. : Nogales and Huachuca Mts., Arizona (*E. J. Oslar*) ; Phoenix, Maricopa Co., Arizona, 1,100 ft., 11.viii.1897 (*R. E. Kunze*) ; Santa Fé and Albuquerque, New Mexico, i & vii.1902 (*E. J. Oslar*). MEXICO : Guadalajara, x.1896 (*Schaus*), x–xi.1893 (*P. H. Goldsmith*).

45. Diatraea schausella, Dyar & Heinr. (Pl. iii, fig. 6).

Diatraea schausella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 24, f. 19.

A male in the British Museum, labelled " GUATEMALA, Panima (*Champion*)," undoubtedly belongs to this species (originally described from two males from Chejel, Guatemala), but is referred to *D. neuricella*, Zell. (= *lineolata*, Walk.) in the " Biologia-Centrali-Americana."

The British Museum also has one female, labelled " COLOMBIA, Choko Prov., Condoto (*H. G. F. Spurrell*)," which agrees in general aspect and in the characteristic pattern of the fore wing, with the above male ; the hind wing, however, is without the light brownish tinge present in the latter, but such a difference is to be expected between the sexes in *Diatraea*. The frons of this female is more sharply pointed at the apex than that of the male (fig. 4, *k*).

The male genitalia indicate a close relationship with *grandiosella* and *muellerella*, but the genitalia of the Colombian female will be seen to be very different from those of the species mentioned.

46. Diatraea pallidostricta, Dyar.

Diatraea pallidostricta, Dyar, Ent. News, xxii, 1911, p. 205 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 16.

Unknown to the writer. Known only by the unique female type in the U.S. National Museum, from São Paulo, Brazil.

A rather large, " pale yellowish-straw "-coloured form, apparently resembling *lineolata*, but with " genitalia as in *saccharalis*."

47. Diatraea lineolata, Walk.* (Pl. iv, fig. 9).

Leucania lineolata, Walker, List. Lep. Ins. Brit. Mus., ix, 1856, p. 100.

Chilo culmicolellus, Zeller, Chilonid. et Crambid., 1863, p. 7 ; Walker, List Lep. Ins. Brit., Mus. xxx, 1864, add., p. 966 ; Zeller, Hor. Soc. Ent. Ross., xiii, 1877, p. 14 (Exot. Microlep., p. 12).

Chilo neuricellus, Zeller, Chilonid. et Crambid., 1863, p. 8 ; Walker, List Lep. Ins. Brit. Mus., xxx, 1864, add., p. 966 ; Zeller, Ent. Zeit., xxxiii, 1872, p. 465 ; Hor. Soc. Ent. Ross., xiii, 1877, p. 13 (Exot. Microlep., p. 11).

Diatraea neuricella, Zeller, Hor. Soc. Ent. Ross., xvi, 1881, p. 162 ; Druce, Biol. Centr.-Amer., Ins., Lep.-Het., ii, 1881–1900, p. 295, pl. lxiv, f. 27.

Diatraea culmicolella (Zell.), Dyar, Ent. News, xxii, 1911, p. 204.

Diatraea lineolata (Walk.), Hampson, Proc. Zool. Soc. Lond., 1895, p. 953 ; Dyar, Ent. News, xxii, 1911, p. 204 ; Proc. U.S. Nat. Mus., xlvii, 1915, no. 2050, p. 319 ; Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 24, ff. 18, 63 (*nec* Barnes & McDunnough, Check List Lep. Bor. Amer., 1917, p. 141, = *D. grandiosella*, Dyar).

Considerable confusion existed respecting the identity of *D. lineolata* and its distribution in the New World before Dyar & Heinrich published figures of the genitalia and thereby definitely limited the application of the name.

The adult of *lineolata* should not be easily confused with any other species of *Diatraea*, and the genitalia of both sexes are quite distinctive. *D. muellerella* is

* *Crambus impersonatellus*, Walker, was considered a synonym of this species by Hampson (1895) and subsequent authors. The type has been examined by the present writer and found to be distinct from *lineolata* ; it is the same species as that described by Dyar & Heinrich as *D. moorella*, but Walker's name has priority (see p. 41).

said to be separable from *lineolata* only with difficulty on external characters ; some comparative notes are offered in the discussion of ***muellerella***, below. The characteristic frons is shown in fig. 2, C–D.

From the " Review of Applied Entomology " we find that a considerable literature has accumulated upon " *Diatraea lineolata*," the name having been applied, apparently indiscriminately, to sugar-cane and corn borers in the United States, Mexico, Cuba, Trinidad and British Guiana. With the exception of Cuba, and possibly Mexico, these references are incorrect, the species concerned in the U.S.A. being *D. grandiosella*, Dyar, and that in Trinidad and British Guiana *D. impersonatella*, Walk.

Van Dine's reference to *D. lineolata* in Cuba (Trop. Plant Res. Foundn., Bull. 2, 1926) is undoubtedly correct, and is interesting in that it definitely establishes sugar-cane as one of the food-plants of this species. Dr. Myers found *lineolata* in Cuba, but the larvae were boring in maize.

There seems to be an element of doubt whether *D. lineolata* is intended where Van Zwaluwenburg uses this name for a serious enemy of sugar-cane in Sinaloa, Mexico (J. Econ. Ent., xix, 1926, p. 664), it being not improbable that either *magnifactella*, Dyar, or *grandiosella*, Dyar, may be the species concerned, rather than *lineolata*.

Cleare's description of the larva of " *lineolata* " (Bull. Ent. Res., xiii, 1922–23, p. 458) is an error for *impersonatella*. The larva of *lineolata* is quite different, and rather closely resembles that of *grandiosella*. A detailed description may be postponed to a further paper that the writer has in mind to prepare, but, discarding technicalities, the larva may be said to be rather stout in form ; the head and the chitinous plate on the prothorax are honey-yellow ; the abdomen is dirty whitish to cream-colour, without any dark chitinized areas surrounding the bases of the body-setae.

59 ♂♂, 92 ♀♀ (B.M., T.M., O.M., I.I.E., Z.M.U.B.) :—MEXICO : Durango State (*Forrer*) ; Misantla, iii.1888 (*F. D. Godman*) ; Teapa, Tabasco (*H. H. Smith*) ; Temax and Valladolid, Yucatan (*Gaumer*). GUATEMALA : (*Conradt*) ; El Tumbador, San Geronimo and Rio Naranjo, 450 ft. (*Champion*). BRITISH HONDURAS : Orange Walk, ix.1917. COSTA RICA : Tuis ; Rio Sixola ; Irazu, 6,000–7,000 ft. (*H. Rogers*) ; Candelaria Mts. (*Underwood*). PANAMA ; Chiriqui (*Ribbe*) ; Bugaba, 800–1,500 ft. (*Champion*) ; Taboga I., Gulf of Panama, 1,000 ft., 17.ix.1924 (*C. L. Collenette*). COLOMBIA : Honda (*Petersen*) ; Boria, Lago Rosario, R. Magdalena ; Rio Dagua (*W. Rosenberg*) ; Condoto, Choko Prov. (*H. G. F. Spurrell*) ; El Banco, Magdalena Valley (*C. Allen*) ; Lago Sapatoza region, Chiriguana, viii–ix.1924 (*C. Allen*). ECUADOR : Rio Cayapas ; Salidero, 350 ft., ii–iii.1901 ; Bulim, 160 ft., xii.1900–ii. 1901 ; Quevedo (*V. Buchwald*) ; Paramba, ii.1897 (*Rosenberg*). BAHAMA Is. : Nassau Is., vii.1898 (*Bonhote*). CUBA : Holguin (*Parish*) ; Matanzas, 1902 (*W. Schaus*) ; Soledad, reared from larvae in maize, ix.1929 (*J. G. Myers*). GRENADA : St. George's, xii.1891 (*C. W. Ellacombe*) ; Fort George, ix.1891. TRINIDAD : xi.1929 (*F. W. Urich*) ; Port of Spain (*F. Birch*) ; St. Ann's (*W. J. Kaye*) ; Maraval, viii–ix.1891 ; Tabaquite, Nareiva Dist. ; Ariapite Valley, vi.1902. BRITISH GUIANA : (*J. Rodway*). DUTCH GUIANA : Paramaribo. FRENCH GUIANA : St. Jean du Maroni. VENEZUELA : Cucuta ; Palma Sola ; Carúpano, xii.1891 (*C. W. Ellacombe*) ; Ciudad Bolivar, vii.–xi.1898 (*S. M. Klages*) ; La Union and La Vuelta, Rio Caura, 1902–1903 (*Klages*) ; Suapure, 1899–1900 (*Klages*).

The geographical range of this species, which is the second most widely distributed of the American species of the genus, is shown in the map (fig. 1).

The writer has seen two specimens, each purporting to be the type of *Chilo culmicolellus*, Zell. One is a small male of *D. saccharalis*, in the Berlin Museum, labelled in copperplate ms. " *Culmicolellus*—Columbia, Moritz," " Typus." The other

is a female of *D. lineolata*, in the British Museum, labelled in Zeller's handwriting " *Chilo culmicolellus* Z. Mon. 7. Columb. M. Berol." ; this example bears a type label attached by Hampson when he was in charge of the collections, and there is little room for doubt that this is actually the type of *culmicolellus*. It is to be noted that Zeller himself sunk this species as *Chilo neuricellus*, Zell.

The writer has seen several specimens in the British Museum labelled by Zeller as *Chilo neuricellus*, Zell., but none of them come from Venezuela, whence the form was described. Neither were specimens found among those sent by Dr. Hering from Berlin. It is to be presumed, therefore, that the type of *neuricellus* is lost.

48. Diatraea muellerella, Dyar & Heinr. (Pl. iv, fig. 8).

Diatraea muellerella, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 25, f. 20.

Hitherto known only by the male and female types in the United States National Museum, from Guerrero, Mexico. A single female in the Tring Museum, also from Mexico, labelled " Cuernavaca, ix.1904 (*Dr. Gadow*)," was determined provisionally as *muellerella* and sent to Washington for comparison with the types. Dr. Heinrich says in his report : " Somewhat darker than the types, but undoubtedly this species."

Dyar & Heinrich state that this species is " Superficially indistinguishable from *lineolata* Walker. Separable on details of the genitalia." The female genitalia are not figured by these authors, but are stated to be " as in *lineolata* except that chitinous band in neck of bursa is a trifle stouter." The frons is similar to that of *D. lineolata* (fig. 2, C, D).

The Tring Museum specimen agrees with typical *lineolata* in general coloration, but the fore wing is rather broader than in that species ; furthermore, there is no trace whatever of a discocellular dot, which can always be detected in *lineolata*. The genitalia, though of similar construction to those of *lineolata*, differ in details, as will be seen from the photographs.

Genus **Xanthopherne,** Dyar & Heinr.

Xanthopherne, Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 29 (Type : *Doratoperas biumbrata*, Schs.).

The venation is essentially the same as in typical *Diatraea* (fig. 5, A, B), but the palpi resemble those of *Doratoperas*, Hampson, to which genus *Xanthopherne* is obviously more closely related.

Besides the genotype, from Guatemala, Dyar & Heinrich include in *Xanthopherne* a single male from Yahuarmayo, Peru, which they erroneously considered to be identical with *Doratoperas fulvescens*, Hampson, described from the same locality, and give figures of the male genitalia under the name *Xanthopherne fulvescens*. Several specimens of *fulvescens*, including the type (in the British Museum), have been examined by the writer and found to be very different from these figures ; *fulvescens* is, by venation, excluded from *Xanthopherne*, whereas the specimen in the U.S. National Museum is, of course, referable to that genus ; the writer has been enabled to examine the latter through the kindness of Dr. Heinrich, to whom he takes pleasure in dedicating the species in question.

In the present paper two additional species are accommodated here, one of them having been described originally in *Diatraea*, the other being new to science. The resulting heterogeneous nature of the genus is unavoidable, but it is fairly certain that a complete revision of the closely related *Doratoperas*, together with some sections

of *Chilo* (sens. lat.), will eventually lead to new definitions for these genera. Meantime, *Xanthopherne* is recognised as defined by its authors.

Nothing is known of the bionomics of the various species, but the larvae are, in all probability, borers in the stems of graminaceous plants.*

Key to the Species of Xanthopherne.

1. Fore wing without discocellular and terminal interneural dots† (Guatemala) ... 1. *biumbrata*, Schs.
   Fore wing with discocellular and terminal interneural dots ... ... 2.
2. Fore wing long and narrow, three times as long as wide; frons flat (fig. 4, *l*) (Peru) ... ... 2. *heinrichi*, sp.n.
   Fore wing rather broad, hardly more than twice as long as wide; frons either strongly convex or triangularly produced, sharply pointed at apex (fig. 4, *m*, *n*) ... ... 3.
3. Fore wing with ground-colour uniformly ochraceous buff, discocellular and a similar dot on median vein below cell, large (0·5 mm. diameter), fuscous; hind wing fuscous or whitish strongly tinged with fuscous on outer margin, without terminal blackish interneural dots; frons strongly convex with a sharp point at apex (fig. 4, *m*) (Venezuela, Peru) ... 3. *bimaculata*, sp. n.
   Fore wing with ground-colour ivory to straw-yellow, mottled with cinnamon-buff and strongly tinged with cinnamon-buff on inner margin, discocellular dot very small, blackish; hind wing whitish, tinged with cinnamon-buff on inner margin, terminal interneural blackish dots present; frons very elongate, triangular, produced to a sharp point at apex (fig. 4, *n*) (Peru) 4. *endothermalis*, Hamps.

1. **Xanthopherne biumbrata,** Schs.

Doratoperas biumbrata, Schaus, Proc. Ent. Soc. Wash., xxiv, 1922, p. 145.
Xanthopherne biumbrata (Schaus), Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 30, f. 75.

Unknown to the writer. Known only by the unique female type in the U.S. National Museum, from Volcan de Santa Maria, Guatemala.

2. **Xanthopherne heinrichi,** sp. nov.

Xanthopherne fulvescens (Hampson), Dyar & Heinrich, Proc. U.S. Nat. Mus., lxxi, 1927, no. 2691, p. 30, f. 27 (nec *Doratoperas fulvescens*, Hamps., Ann. Mag. N.H., (9) iv, 1919, p. 61).

♂. Palpus light buff tinged with cinnamon-buff. Antennal shaft honey-yellow with sparse light buff scales. Head light buff slightly tinged with cinnamon-buff, sides of vertex cartridge-buff. Thorax cinnamon-buff tinged with cinnamon anteriorly and laterally, fading to light buff posteriorly. Tergum light buff to vinaceous buff, tinged with avellaneous to wood-brown, proximal two segments cinnamon. Pectus light buff tinged with warm buff. Legs the same; a large tuft of long hair-like scales on the inner margin of hind tibia, this tuft being wood-brown tinged with cinnamon, at the base, fading gradually and evenly through light buff to cartridge buff at the apex of the tibia. Venter cartridge-buff tinged with some warm buff. Fore wing light ochraceous buff tinged with warm buff; a cinnamon-buff to cinnamon

* The writer has found the larvae of *Doratoperas atrosparsellus*, Walk., in abundance boring in the stems of the giant grass, *Gynerium sagittatum*, Beauv., in Venezuela.

† These characters are taken from Dyar & Heinrich. Schaus, in his original description, remarks " minute terminal cinnamon points on interspaces."

shade on inner margin between the bases of the oblique lines ; the entire surface of wing somewhat mottled with cinnamon, and irrorated with numerous scattered individual fuscous-tipped scales ; the veins faintly lined in cinnamon-buff ; a minute blackish discocellular dot ; two faint irregularly denticulate oblique avellaneous to wood-brown lines, the first from costa near apex to inner margin about one-third its length from base, rather widely bowed around and below the cell ; the second from apex to inner margin below apex of vein 1c ; a terminal series of small blackish interneural dots, those above veins 1c and 2 rather larger and more distinct than the others. Hind wing whitish tinged with light buff ; the inner margin with long hair-like warm buff to ochraceous buff scales, which are also present to some extent on median vein at base ; a small fuscous <-shaped patch of scales on vein 6 at a point where an imaginary continuation of vein 4 from base would intersect it ; a terminal series of fuscous black interneural dots, those above veins 1b, 1c and 5 larger and more conspicuous than the others. Underside of fore wing light buff tinged with vinaceous buff, tinged with warm buff on costa from base to apex and on the veins ; discocellular and terminal dots distinct, blackish ; a small patch of cinnamon scales at base above the point where the frenulum engages ; of hind wing cartridge-buff, slightly tinged with light buff on costa and outer margin, slightly tinged with ochraceous buff at inner angle, the markings as on upperside. Expanse 44 mm.

The frons is quite flat, not projecting between the eyes (fig. 4, *l*).

PERU : Yahuarmayo, 1,200 ft., 2 ♂♂, iv.1912.

Holotype ♂ in United States National Museum, and one paratype ♂ in British Museum.

The holotype is the actual specimen discussed, and whose genitalia are figured, by Dyar & Heinrich under the erroneous determination of *X. fulvescens*, Hamps. In the type and six other specimens of *Doratoperas fulvescens* seen by the writer, the hind wing is dark, inclined to fuscous, and the tuft of hair-like scales on the hind tibia is much smaller than in *heinrichi*. The male genitalia of *Doratoperas fulvescens*, Hamps , are illustrated (Pl. ii, figs. 9, 10).

The present species is referred to *Xanthopherne* on the short anastomosis of veins 11 and 12 in the fore wing. In all other respects it is typically a *Doratoperas*, the shape of the wings being exactly as in *D. atrosparsellus*, Walk. (genotype) and differing considerably from the two other species of *Xanthopherne* before the writer. *D. fulvescens*, on the other hand, has the fore wing of similar shape to *X. bimaculata*, but veins 11 and 12 are quite free, so that inclusion in *Xanthopherne* is not permissible.

3. Xanthopherne bimaculata, sp. nov. (Pl. ii, figs. 7, 8 ; Pl. iv, fig. 7).

♂, ♀. Palpus warm buff streaked with avellaneous. Antennal shaft dark brownish with sparse light buff to warm buff scales. Head warm buff tinged with cinnamon-buff to buffy brown, lighter (light buff) in front and sometimes on a median line on vertex. Thorax warm buff tinged with buffy brown. Tergum vinaceous buff to avellaneous, somewhat infuscate, proximal two segments cinnamon to ochraceous tawny. Pectus light buff tinged with warm buff. Legs the same, sometimes tinged with cinnamon-buff ; hind tibia of ♂ hairy but without a large tuft of hair-like scales. Venter light buff. Fore wing light ochraceous buff, tinged with warm buff to ochraceous buff except on a narrow streak extending from just before middle of cell to outer margin between veins 5 and 6 and on a similar streak on basal two-thirds of the median fold, tinged with some fuscous at apex and on an area on and below median vein as far as base of vein 4 ; the entire surface sparsely irrorated with scattered individual fuscous-tipped scales which tend to run into lines interneurally ; the veins slightly infuscate ; a rather large fuscous discocellular dot ; a similar dot

immediately below median vein at base of vein 2; two oblique rows of fuscous dots, the first rather short, extending from vein 6 near base in a curve (concavity basad) around the cell to the large median dot already mentioned; the second, consisting of minute crescent-shaped dots between the veins, from the fuscous patch at apex to inner margin at apex of vein 1c; a terminal series of fuscous blackish interneural dots. Hind wing sordid whitish tinged with ochraceous buff on apical half, tinged with some brownish on outer margin; a faint fuscous terminal line with blackish interneural dots. Underside of fore wing light buff strongly tinged with avellaneous to wood-brown except on costa, outer margin and a streak from middle of cell extending beyond, between veins 5 and 6; the veins slightly infuscate; discocellular dot faint; terminal dots distinct, blackish; of hind wing sordid whitish tinged with light buff, strongly tinged with warm buff to ochraceous buff on costa and outer margin below apex Expanse, ♂, 32·5—35 mm.; ♀, 38 mm.

The frons is strongly convex with the sides tapering to a sharp point at the apex (fig. 4, *m*).

7 ♂♂, 2 ♀♀:– PERU: La Oroya, R. Inambari, 3,100 ft., ix.1904 (holotype ♂), iii.1905, xi–xii.1905 and i 1906 (allotype ♀) (*G. Ockendon*); Tinguri, Carabaya, 3,400 ft., i.1905 and viii.1905 (*Ockendon*). VENEZUELA: La Union, Rio Caura, x.1902 (*S. M. Klages*).

Holotype ♂ in Tring Museum; paratypes in Tring Museum, British Museum and U.S. National Museum.

The two longitudinal light-coloured streaks contrasting against the warm brownish ground-colour, and the two conspicuous fuscous dots, give the fore wing a very characteristic appearance, rendering the species easily recognisable.

The genitalia suggest a closer relationship with *X. endothermalis* than with other species in the genus.

4. **Xanthopherne endothermalis,** Hamps. (Pl. ii, figs. 5, 6).

Diatraea endothermalis, Hampson, Ann. Mag. N.H., (9) iii, 1919, p. 544.

Hampson, guided by wing-venation, included this species in *Diatraea*. The moth is, however, obviously out of place in that genus, and the structure of the palpi compel us to refer it to *Xanthopherne*. From some points of view this species might be considered as intermediate between *bimaculata*, sp. n., and *heinrichi*, sp. n., for whereas in general form and in the structure of the genitalia it is closest to the former, the coloration and the presence of a tuft of long hair-like scales on the hind tibia of the male suggest an equally close relationship with the latter.

The frons is greatly elongated, triangular, with the sides tapering to form a strongly pointed apex (fig. 4, *n*).

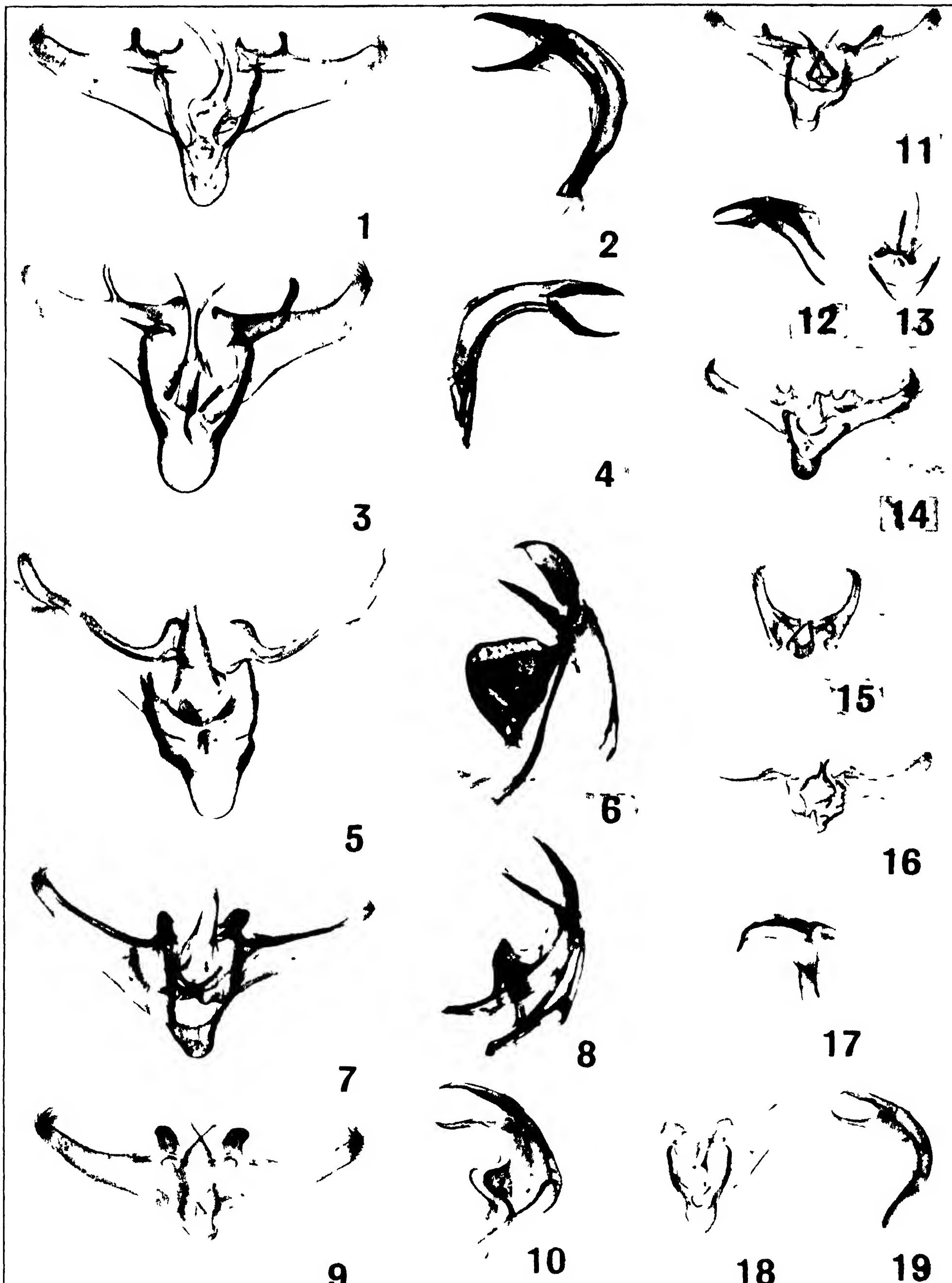
Besides the male type (in the British Museum), labelled "PERU, Yahuarmayo, 1,200 ft., iv–v.1912," the writer has seen one other specimen, also a male, in the Tring Museum: "PERU, La Union, R. Huacamayo, Carabaya, xi.1904 (*G. Ockendon*)"

Explanation of Plate I.

Male genitalia of *Diatraea*.

Fig. 1. *Diatraea amazonica*, sp. n.
„ 2. „ „ „
„ 3. „ *rufescens*, sp. n.
„ 4. „ „ „
„ 5. „ *albicrinella*, sp. n.
„ 6. „ „ „
„ 7. „ *luteella*, sp. n.
„ 8. „ „ „
„ 9. „ *flavipennella*, sp. n.
„ 10. „ „ „
„ 11. „ *entreriana*, sp. n.
„ 12. „ „ „
„ 13. „ „ „
„ 14. „ *argentina*, sp. n.
„ 15. „ *lentistrialis*, Hamps.
„ 16. „ *incertella*, sp. n.
„ 17. „ „ „
„ 18. „ *morobe*, Dyar.
„ 19. „ „ „

(*Note.*—The figures of the tegumen, uncus and gnathos are slightly more magnified than those of the harpes, vinculum and anellus.)



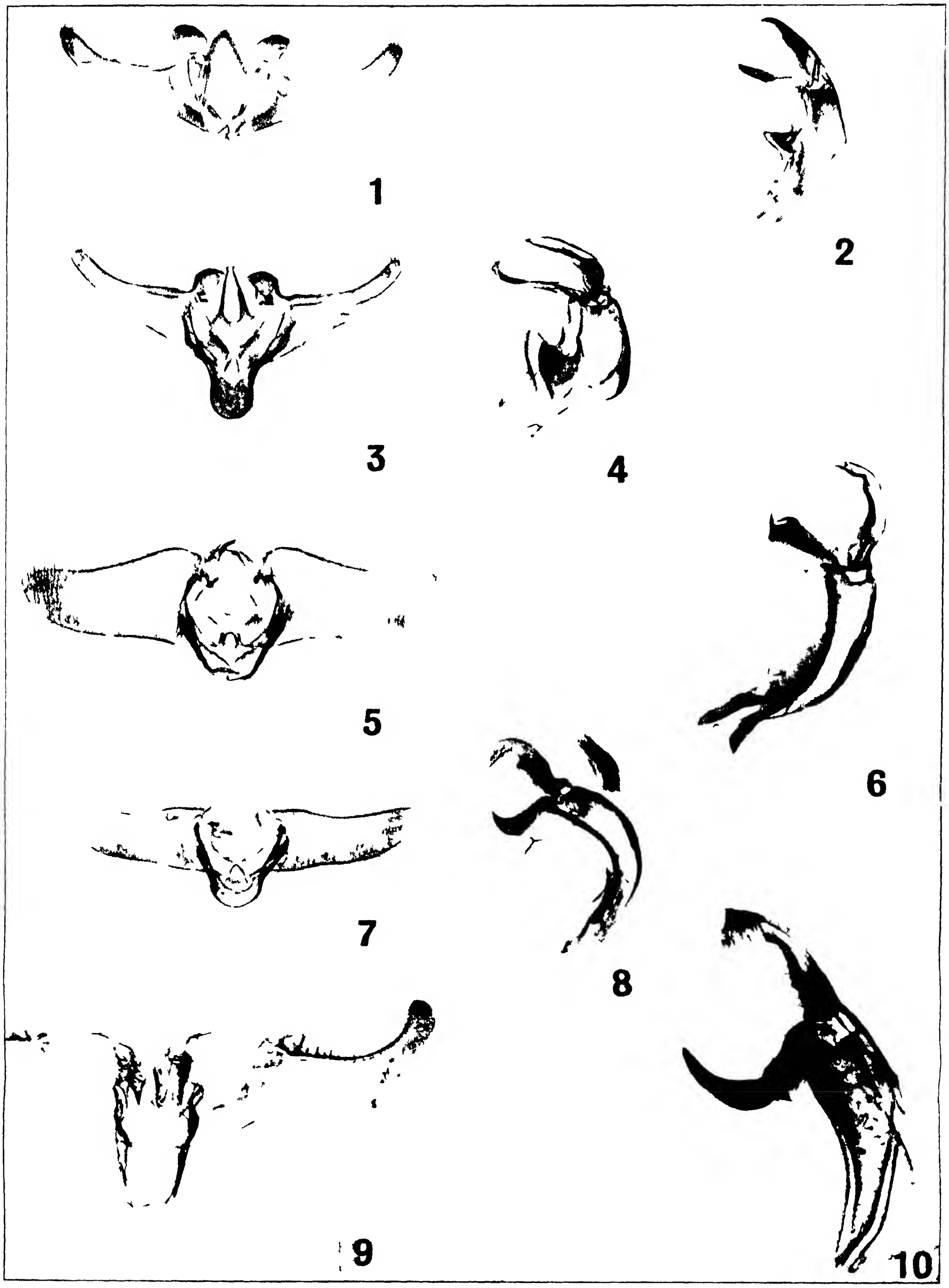
Male genitalia of Diatraea.

EXPLANATION OF PLATE II.

Male genitalia of *Diatraea*, *Xanthopherne* and *Doratoperas*.

Fig. 1. *Diatraea indigenella*, Dyar & Heinr.
„ 2. „ „ „
„ 3. „ *continens*, Dyar.
„ 4. „ „ „
„ 5. *Xanthopherne endothermalis*, Hamps.
„ 6. „ „ „
„ 7. „ *bimaculata*, sp. n.
„ 8. „ „ „
„ 9. *Doratoperas fulvescens*, Hamps.
„ 10. „ „ „

(*Note.*—The figures of the tegumen, uncus and gnathos are slightly more magnified than those of the harpes, vinculum and anellus.)

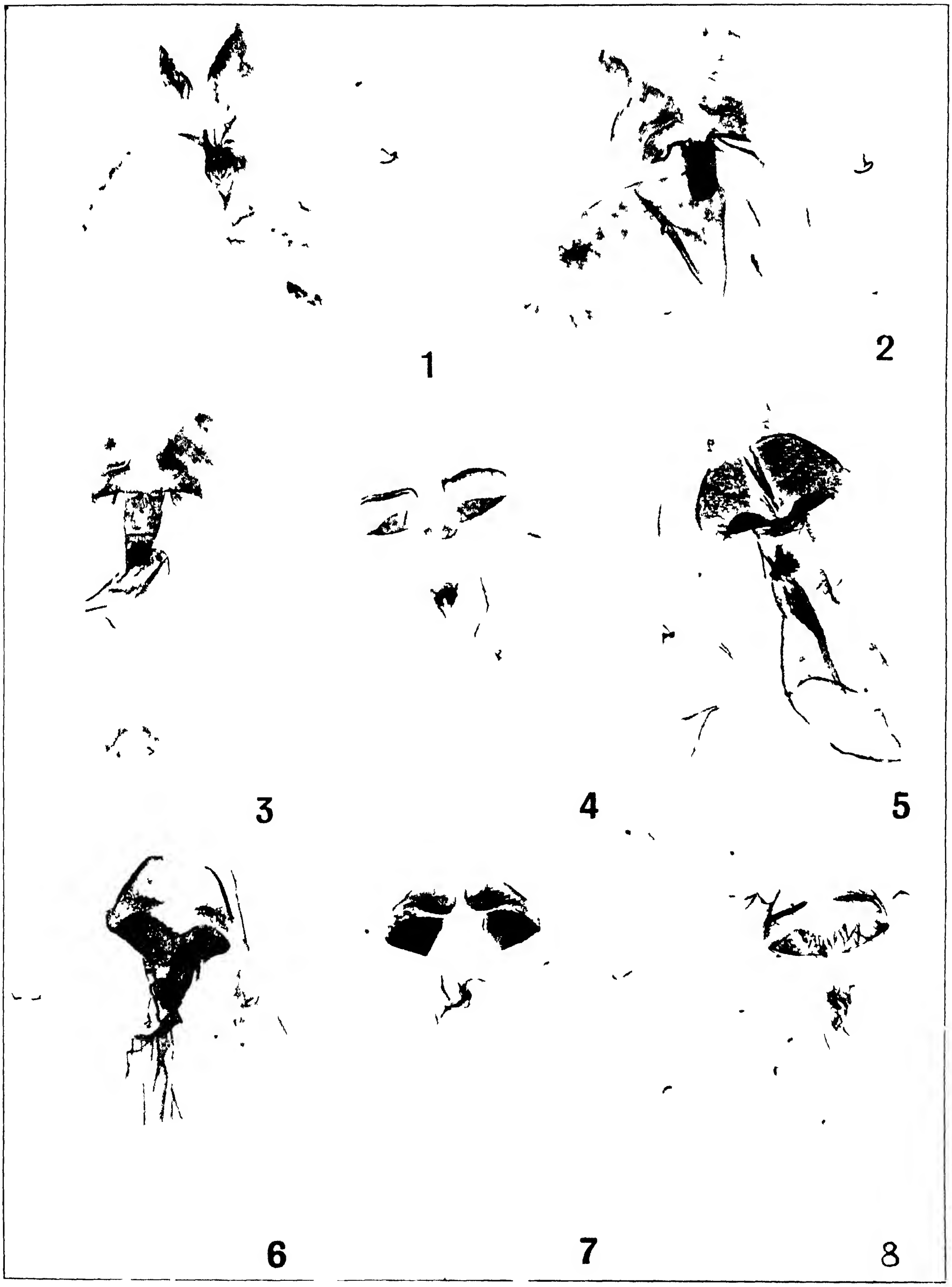


Male genitalia of Diatraea, Xanthopherne, and Doratoperas.

Explanation of Plate III.

Female genitalia of *Diatraea*.

Fig. 1. *Diatraea crambidoides*, Grt.
„ 2. „ *impersonatella*, Walk.
„ 3. „ „ „
„ 4 „ *angustella*, Dyar.
„ 5. „ *busckella*, Dyar & Heinr
„ 6. „ *schausella*, Dyar & Heinr.
„ 7. „ *tabernella*, Dyar.
„ 8. „ *saccharalis*, Fabr.

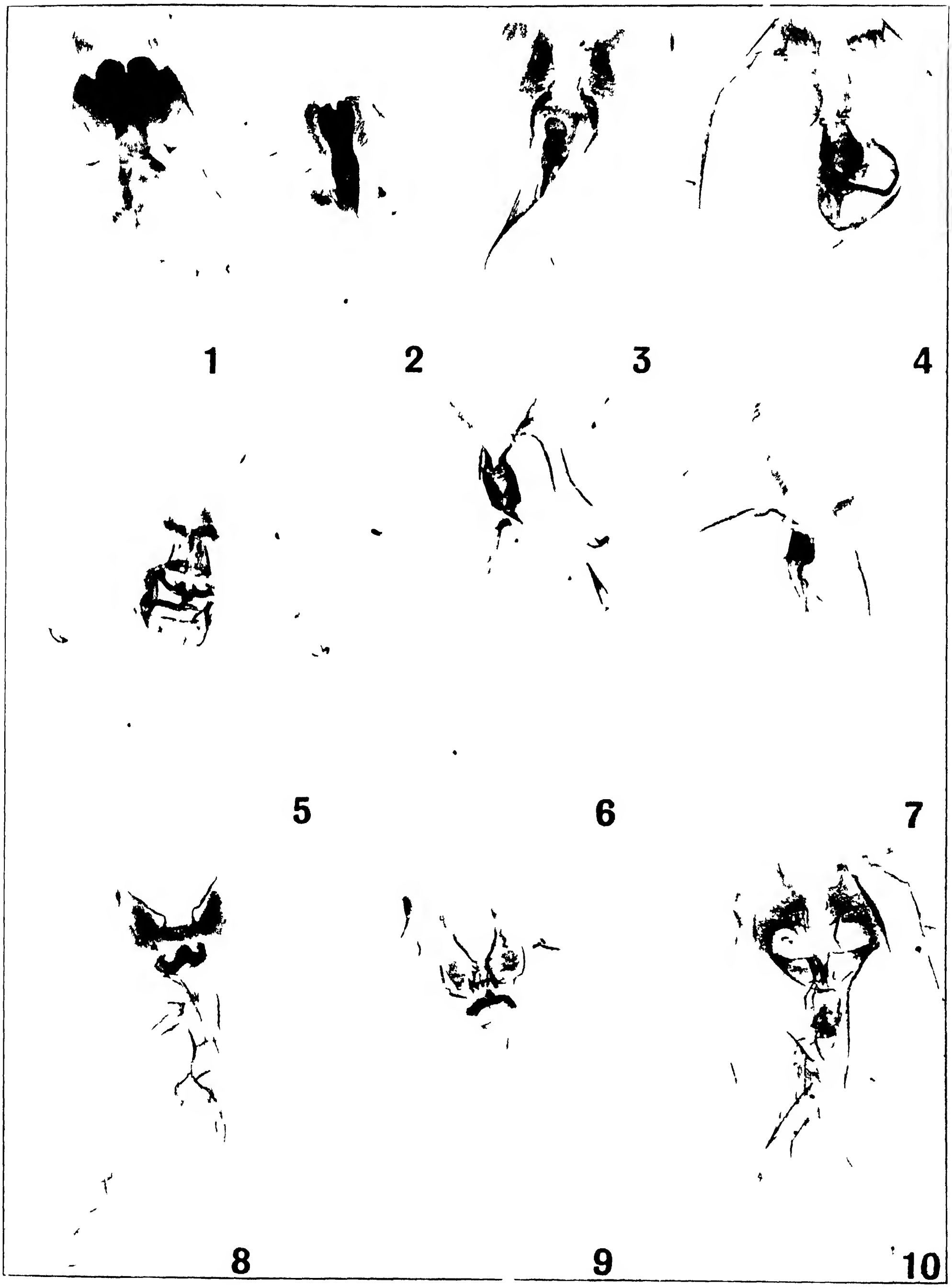


Female genitalia of Diatraea

Explanation of Plate IV.

Female genitalia of *Diatraea* and *Xanthopherne.*

Fig. 1. *Diatraea strigipennella*, Dyar.
„ 2. „ *entreriana*, sp. n.
„ 3. „ *indigenella*, Dyar & Heinr.
„ 4. „ *amazonica*, sp. n.
„ 5. „ „ „
„ 6. „ *rufescens*, sp. n.
„ 7. *Xanthopherne bimaculata*, sp. n.
„ 8. *Diatraea muellerella*, Dyar & Heinr.
„ 9. „ *lineolata*, Walk.
„ 10. „ *luteella*, sp. n.

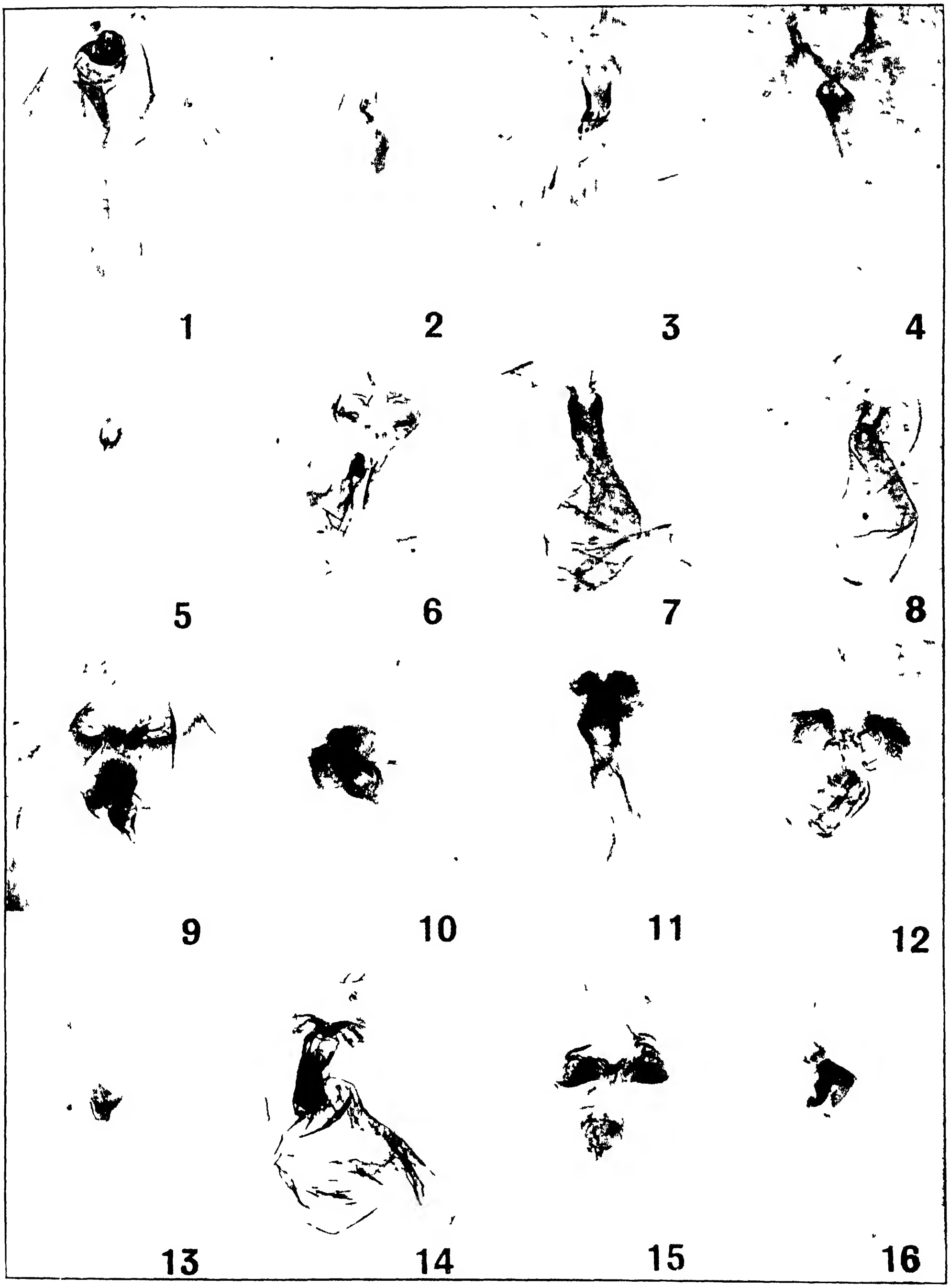


Female genitalia of Diatraea and Xanthopherne

Explanation of Plate V.

Female genitalia of *Diatraea.*

Fig. 1 *Diatraea brunnescens*, sp. n.
,, 2. ,, *argentina*, sp. n.
,, 3. ,, *amnemonella*, Dyar.
,, 4. ,, *obliqualis*, Hamps.
,, 5. ,, ? *minimifacta*, Dyar.
,, 6. ,, *flavipennella*, sp. n.
,, 7. ,, *canella*, Hamps.
,, 8. ,, sp. n. ined. prox. *obliqualis*, Hamps.
,, 9. ,, *pedibarbata*, Dyar.
,, 10. ,, *cayenella*, Dyar & Heinr.
,, 11. ,, ,, ,,
,, 12. ,, *continens*, Dyar.
,, 13. ,, *fuscella*, Schs.
,, 14. ,, *suffusella*, sp. n.
,, 15. ,, *albicrinella*, sp. n.
,, 16. ,, *grandiosella*, Dyar.



Female genitalia of Diatraea.

MOSQUITOS BREEDING IN TREE CAVITIES IN QUEENSLAND.*

By R. HAMLYN-HARRIS, D.Sc.,
City Entomologist, Brisbane.

Beattie & Howland's recent studies of the bionomics of some tree-hole mosquitos emphasize the importance of the food factor, total organic nitrogen, and the apparent lack of correlation between hydrogen ion concentration and larval incidence. In Queensland mosquitos selecting such breeding-places are with a few exceptions distinctly arboreal, and the presence of domestic mosquitos in tree-cavities is dependent upon proximity to human habitations. It is a curious fact that when this is the case both *Aëdes argenteus* and *Culex fatigans* will breed in smaller accumulations of water than *Aëdes notoscriptus* does.

Appended herewith are the results of a recent survey made in midsummer of trees situated within the Brisbane Area of 385 square miles. Pine trees and gum trees do not lend themselves to the production of cavities and therefore offer very little opportunity for breeding.

Mosquitos breeding in Trees in Brisbane (Midsummer).

No. of trees examined	No. of cavities	Cavities containing mosquitos	Species of mosquitos	Percentage of each species found
1 299	196	64	*A. argenteus* alone . .	17·1
			A. notoscriptus alone ...	71·9
			A. argenteus and *notoscriptus* in association	9·4
			C. fatigans alone ...	1·6

Trees in which Mosquitos were found.

Ficus benjamina	Weeping Fig ...	... Exotic.
Ficus macrophylla	Moreton Bay Fig ...	... Native.
Ficus hilli	Fig	... Native.
Poinciana regia	Poinciana ...	... Exotic.
Stenocarpus sinuatus	Wheel of Fire tree...	... Native.
Macadamia ternifolia	Queensland Nut ...	... Native.
Cinnamomum camphora ...	Camphor Laurel ...	... Exotic.
Erythrina tomentosa	Coral tree ...	... Exotic.
Catanospermum australe ...	Moreton Bay Chesnut	... Native.
Caesalpinia ferrea	—	... Exotic.
Schotia latifolia	—	... Exotic.

	Examined	Cavities	Percentage containing mosquitos
Poincianas	17	11	64·7
Figs	554	133	24·0
Other trees	728	52	11·3

The poincianas hold the highest actual percentage, but on account of the far greater number of figs containing potential breeding cavities, the latter constitute a

* From the Entomological Section, Department of Health, Brisbane City Council.

greater actual menace. The amount of water contained in each cavity varies considerably with the time of year. After measuring the contents of 20 cavities we are able to state that these averaged as much as 593·1 cc. In general, the older a fig tree is, the greater the possibility of its forming cavities. Had the examinations been confined to trees only over 18 inches in girth, the percentage would have been very much higher.

The following trees also give rise to cavities, but these seldom contain larvae :—

Spathodea campanulata (Tulip tree)	Exotic.
Croton oblongus	Exotic.
Erythrina caffra (Coral tree)	Exotic.
Bauhinia purpurea	Exotic.
Alstonia scholaris (Milky Pine or Dita Bark tree)	Native.
Lagunaria patersoni (Pyramid tree)	Native.
Albizzia stipulata	Exotic.
Ficus glomerata (Cluster Fig)	Native.

In parks, public grounds, roadways, etc., trees situated within easy distance of dwellings show a tendency to breed *Aëdes argenteus* rather than any other species. In a survey of such trees we found 50 per cent. positives of this species, whereas in localities where the trees are situated at some distance, such as would be the case in Botanical Gardens, *A. notoscriptus* is usually found to occur in association with species of sandflies (*Culicoides*), Chironomid and Syrphid larvae, and a few other insects. Unless the tree is situated in close proximity to a bush-house or other spot of a selective nature in the vicinity of human habitations, *A. argenteus* and *C. fatigans* rarely select tree-cavities in Brisbane.

Aëdes notoscriptus is a common mosquito in the Queensland bush. It is often particularly noticeable in areas apparently devoid of water. This is important, as the question is often asked why such " dry " stretches, especially in drought time, are so often heavily infested with adult mosquitos when no water is visible for miles. Systematic search has revealed the fact that though other sylvan mosquitos occur, *A. notoscriptus* makes up by far the largest percentage, being traceable in most cases to enormous rot-holes capable of holding several gallons of water. These evaporate but slowly and turn out prodigious numbers of *A. notoscriptus*.

We have found the control of tree-cavities an exceptionally simple matter. When we first commenced operations, we were under the impression that only the use of cement would be adequate in order to eliminate such breeding-places. In actual practice all that is necessary is to fill the spaces with heavy soil, which remains effective for a long time. In the intensive work in our area the Inspector usually carries a small trowel with him and fills up these holes on the spot, so that as a consequence we are never worried with them after they have been once filled in properly.

Paradichlor-benzine is useful in controlling *Aëdes notoscriptus* and other mosquitos breeding in Bromelias and places of a similar nature, including flower vessels in cemeteries. It has been equally effective in tree-cavities.

A NEW SPECIES OF *ERYTHRONEURA* (HOMOPTERA, JASSOIDEA) INJURIOUS TO FRENCH BEANS (*PHASEOLUS VULGARIS*) IN THE SUDAN.

By W. E China.

The following description is based on material received for identification from the Imperial Institute of Entomology

Erythroneura lubiae, sp. n.

Colour :—Pale green covered with a whitish pruinosity, middle of pronotum and apices of tibiae, tarsi and ovipositor of ♀, slightly darker green ; a spot at middle of apical margin of pronotum and a broad stripe down middle two-thirds of scutellum,

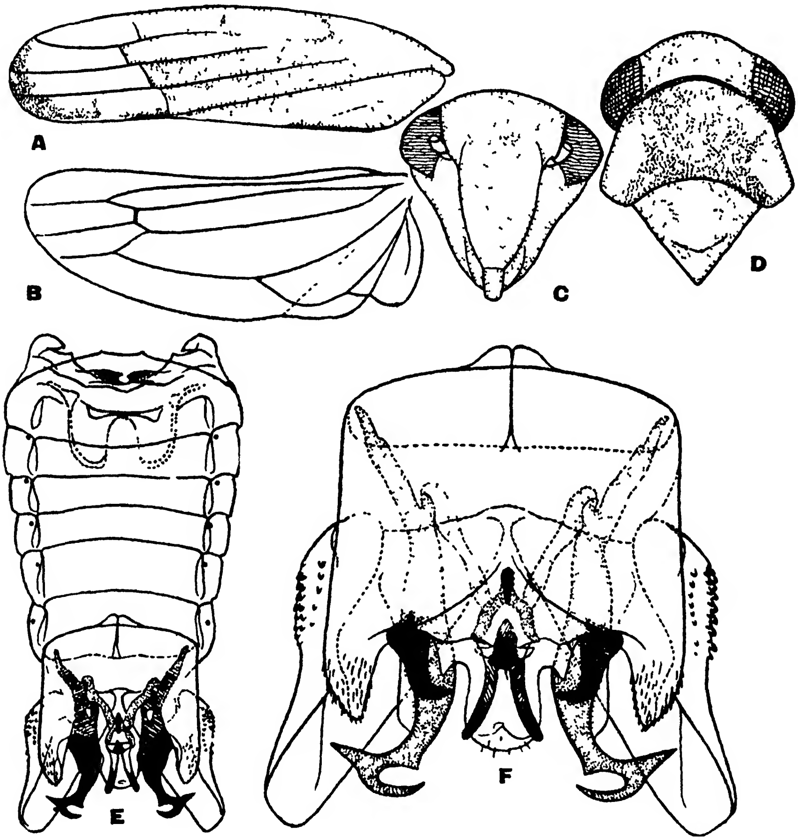


Fig 1 *Erythroneura lubiae* sp n *a* tegmen *b* wing *c* face *d* head pronotum, and scutellum (from above), *e*, abdomen showing internal basal abdominal pouches, *f*, male genitalia, showing striking hook shaped parameres

opaque white Eyes dark greenish grey, apex of rostrum brown In some female specimens the head and pronotum are uniformly greenish yellow and the white spots are obsolete. Tegmina more or less hyaline, the veins, clavus, brachial and suprabrachial areas, sub-opaque, suffused with pale green or greenish yellow ; the membrane infuscate towards apex and along inner margin ; claval commissure very narrowly and extreme inner margin of membrane beyond apex of clavus, dark

brown; costal plaque distinct, pallid. Wings whitish hyaline, faintly infuscate towards apex, veins white. Abdomen pale whitish green, basal tergite and anal segment greenish yellow. Tibial spines white.

Structure :—Ocelli absent; head as wide across eyes as pronotum across humeral angles (47 : 47)*; seen from above slightly less than half as long in middle as wide between eyes (13 : 27), only slightly longer than length at eye (13 : 11); face (including clypeus) about 2·25 times as long as wide between antennae (50 : 22); frons three times as long as clypeus (36 : 12), which is apically sub-angulate. Pronotum about half as long as wide across humeral angles (23 : 47). Scutellum distinctly wider at base than length of side (32 : 27), disc transversely impressed on posterior half. Tegmina extending well beyond apex of abdomen, transverse veins parallel, rather indistinct; first apical cell elongate with its basal vein almost obsolete, second apical cell widening suddenly apically, its sides sub-parallel for basal two-thirds. Subgenital plates (♂)† broad at base, where the lateral surface is densely tuberculate, truncated at apex; parameres flattened, curiously hook-shaped (fig. 1, *f*). Last ventrite (♀) posteriorly truncate; ovipositor extending slightly beyond apex of abdomen.

Total length, 3·2 mm.

SUDAN: Kaduru, "on vine," numerous specimens (including type), 20.vii.1930 (*J. W. Cowland*); Khartoum, "from Lubia hilwa" (*Phaseolus vulgaris*), numerous specimens, 12.vii.1930 (*H. W. Bedford*); Wad Medani, "off leaves of Lubia afin" (*Phaseolus vulgaris*), 3 specimens, 1.iv.1920 (*H. H. King*).

Differs from all other Ethiopian species of *Erythroneura* in the shape of the head, combined with the uniform pale green colour without black spots but with the narrow infuscation of the claval commissure. The male parameres are very striking. Attention is drawn to the peculiar bilobed internal structure at the base of the abdomen in the male (fig. 1, *e*). This structure, which occurs in some other genera and species of Jassoidea, is of unknown function and awaits investigation.

* Measurements in divisions of micrometer scale, 63 = 1 mm.

† Genitalia described from microscopical preparation.

A COMPARISON OF THE IMMATURE STAGES OF *EUMERUS TUBERCULATUS*, ROND., AND *SYRITTA PIPIENS*, LINN. (SYRPHIDAE).

By W. E. H. Hodson, A.R.C.S.,
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Introduction.

The larval stages of two species of Syrphid flies, namely, *Eumerus tuberculatus* and *E. strigatus*, are frequently found in rotting narcissus bulbs, in iris and tulip, and in vegetable roots, such as parsnip. The writer[2] has shown that frequently the decay, at least in the narcissus, is directly attributable to the presence of these larvae and that they must therefore be considered to be primary pests. It was further shown that, contrary to current opinion, the predominant species at the time of writing was *E. tuberculatus*. In passing it may be recorded that this predominance has, in each subsequent year, become more marked, until at the present time *E. strigatus* has ceased to rank as a bulb pest, at least in South-West England, Holland, and probably the Irish Free State. The larvae of the two species are very similar to one another, and it has not been found possible to separate the species, with any great degree of accuracy, during the immature stages. In the adult form, as shown by Collin,[1] separation is easily effected. In the course of experimental work with these flies a third, and superficially somewhat similar Syrphid, namely *Syritta pipiens*, L., was frequently bred from decayed narcissus bulbs.

Historical.

Verrall[4] describes *Syritta pipiens* and records that it is exceedingly common and practically cosmopolitan in habitat, ranging throughout Europe, parts of Asia, South Africa and North America. The only reference in recent literature to the immature forms of the fly is that by Lundbeck,[3] who reports—" The pupa was taken in Damhusmosen in heaps of leaves and other vegetable matter in August (Schilick)." Lundbeck further gives a brief description, taken from Beling, of the larval and pupal forms found under rotten straw and other vegetable matter in March.

The fact that the fly appears with some regularity in association with *Eumerus tuberculatus* suggested to the writer the possibility that the larvae might also feed upon plant tissues. Careful search was made through a large number of samples of decaying narcissus bulbs, but larvae or pupae markedly dissimilar from those of *Eumerus* were not found. A search through preserved material gave more promise, for numerous larvae were discovered which bore a strong resemblance to those described by Collin[1] in 1920, from material obtained from decaying parsnip.

By 1927 many commercial growers of narcissus in South-West England had become fully aware of the extent to which infestations of bulb-fly larvae menaced their crops. As a result, numerous samples of attacked bulbs were being submitted to the writer for examination. In addition several growers sent in samples of manure, which they stated contained bulb-fly larvae, and expressed the fear that these pests were being spread rapidly by means of such manure. Superficially larvae received from such sources bore some resemblance to those of *Eumerus*, but close examination revealed slight but obvious differences. Again in 1928 further samples of similar larvae were received, obtained from farm-yard manure, from tulip bulbs and from heaps of vegetable refuse. This latter was a site similar to that from which Lundbeck[3] recorded pupae. In each case, on breeding out the larvae, *Syritta pipiens* was obtained. It had in the meantime been observed that the fly was never bred from bulbs other than exceedingly decayed ones. Repeated attempts were made to induce the larvae to attack and feed upon healthy plant tissues. The technique

employed was that which had given successful results when working with the larvae of *Eumerus*.[3] In no case could an attack be induced. It would therefore seem that we are justified in considering the larvae to be only scavengers, feeding entirely upon refuse and badly decayed tissues and therefore of little or no economic importance. Further proof of this is afforded by an examination of the cephalo-pharyngeal

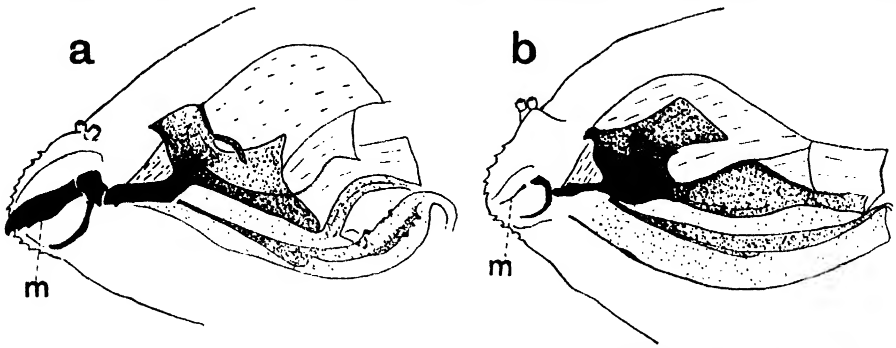

Fig. 1. The cephalo-pharyngeal skeleton of larvae of : (*a*) *Eumerus tuberculatus*, Rond. ; (*b*) *Syritta pipiens*, L. ; — *m*, mandibular sclerite.

skeletons of the respective larvae (fig. 1). In *Syritta* the mandibular sclerites are only vestigial, in marked contrast to those of *Eumerus*, which are powerful, toothed, and obviously well suited to tearing down living plant tissues.

Nevertheless, the presence of *Syritta* larvae in manure, refuse and decayed bulbs, frequently causes undue alarm to commercial bulb-growers. For this reason a brief

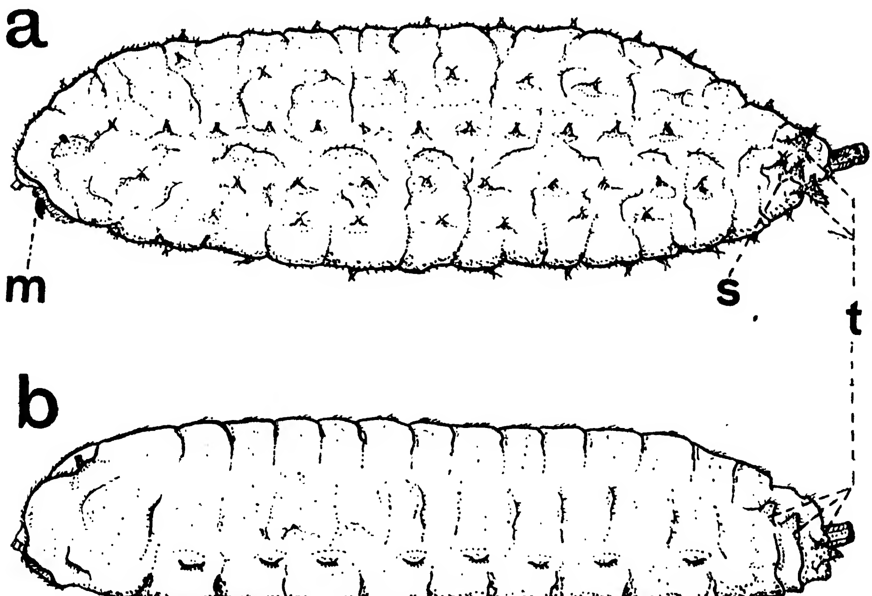

Fig. 2. Larvae of : (*a*) *Eumerus tuberculatus* ; (*b*) *Syritta pipiens* ; — *m*, mandibular sclerite ; *t*, tubercles ; *s*, twin-tubercle.

description of the larval and pupal stages of both *Eumerus tuberculatus* and *Syritta pipiens* is desirable, in order that confusion of the two may be avoided. In passing, it may be noted that larvae of *Eumerus tuberculatus* and of *E. strigatus* have sometimes been found in manure, but have never been reared to maturity upon this food.

Description of Larvae (fig. 2).

Eumerus tuberculatus, Rond

Subcylindrical, greyish white Anterior spiracular processes dorsal, widely separated, prominent, chestnut-red Posterior pair fused, prominent, slightly swollen at apex, chestnut-red. Antennae bifid, less divergent, larger Integument clothed with minute brown scattered spines, segments bearing rows of small tubercules carrying few larger but otherwise similar spines On last pseudo-segment, on each side of posterior spiracular process and slightly ventral to it, a large tubercle. Slightly dorsal to this and on the penultimate pseudo-segment a smaller twin tubercle, each twin bearing a cluster of small curved spines More dorsally, on same pseudo-segment a third tubercle, intermediate in size between the preceding ones. Tubercles unicolorous with rest of integument Buccal armature well developed, mandibular sclerite strong, toothed, tip visible externally Length, 7–9 mm

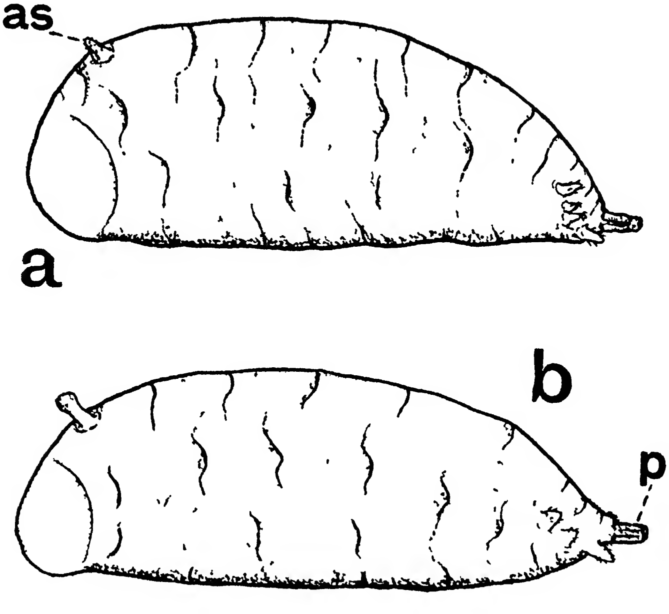

Fig 3 Pupa of (*a*) *Eumerus tuberculatus* (*b*) *Syritta pipiens* — *as p*, anterior and posterior, spiracular process

Syritta pipiens, Linn.

Subcylindrical, greyish white Anterior spiracular processes dorsal, less widely separated, less prominent, darker Posterior pair fused, less prominent, less swollen, darker. Antennae bifid, more divergent, smaller. Integument clothed with finer, hair-like, whitish spines, small tubercles less prominent except on ventral surface, where seven pairs may be distinguished, each carrying several larger brown spines. On last pseudo-segment on each side of posterior spiracular process and slightly ventral to it, a large tubercle. Slightly dorsal to this and on penultimate pseudo-segment a smaller single tubercle. On the preceding pseudo-segment a third and similar tubercle. Tubercles unicolorous with rest of integument Buccal armature reduced, mandibular sclerite vestigial, tip not visible externally Length, 7–9 mm.,

Description of Pupae (fig. 3).

Eumerus tuberculatus, Rond.

Pear-shaped, flattened ventrally, yellowish white, darkening later. Integument tough, skin armature and tubercles present but less prominent than in larva. Anterior spiracular processes not visible in freshly formed pupa, protruded later, less prominent, terminating in blunt point. Posterior spiracular process as in larva. Length, 6–7 mm.

Syritta pipiens, Linn.

Pear-shaped, flattened ventrally, yellowish white, darkening later. Integument tough, skin armature and tubercles present but less prominent than in larva. Anterior spiracular processes not visible in freshly formed pupae, protruded later, more prominent, terminating in a very distinct knob. Posterior spiracular process as in larva. Length, 6–7 mm.

References.

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(3) Lundbeck, W. Diptera Danica, part v, London, 1916.

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OXYGEN ABSORPTION OF NATURAL WATERS IN NAIROBI WITH REFERENCE TO ANOPHELINE MOSQUITOS.

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and

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The following data have been gathered over a period of about one year (January to December 1929) in the Nairobi District, Kenya Colony.

It was thought that the organic content of natural waters would certainly offer some indication of their suitability for the breeding of Anopheline mosquitos and that an investigation might suggest some definite line of approach to this intensely complex problem.

During November and December 1928, certain water sources were selected by one of us (C. B. S.), in widely separated parts of the district, for weekly sampling. In each separate area some four to eight places were chosen for routine searches for Anopheline larvae; thus in the Q area (Table II) seven places were searched every week and in the B area (Table I) six places. From the places in each area two were chosen for routine oxygen absorption tests, one with Anopheline larvae and one without, water from these same two places being sampled and tested weekly. Thus in the Q area, spots Q 5 and Q 6 were used for this purpose, and in the B area B 3 and B 5. It is necessary to emphasise the fact that these places were separated from one another by distances of 50 to 150 yards. The choice of the source of water to be sampled was made purely on the presence or absence of Anopheline larvae at the beginning of the work.

The weekly nature of the sampling was interfered with very considerably by holidays and sickness of the trained African mosquito boy who was entrusted, under supervision, with the daily collection. As nearly as possible, however, the original routine was adhered to.

The samples were brought to the Laboratory and analyses were carried out by one of us (D. H.) on the following forenoon. The inorganic reducing figures were taken by allowing the reaction with acid permanganate to continue for 15 minutes at laboratory temperature and in ordinary daylight. After four hours under these conditions the second titration was carried out, and the difference between this and the 15-minute figure was taken as the oxygen absorbed by the organic matter in the water. It is recognised that the oxygen absorption is seldom complete even after that length of time, but it is assumed that the figures are comparable, because of the fact that the times were the same in all cases.

The complete data have been recorded in five tables and a chart, which have been filed in the library of the Imperial Institute of Entomology. For our present purpose it is sufficient to give merely a summary of these tables.

TABLE I.

Breeding-place	Sample	Number	Average			Ratio of organic to inorganic
			After 15 minutes	After 4 hours	Difference	
B 3	With *A. costalis* ...	8	0·291	0·486	0·195	1 : 1·492
	Without *A. costalis* ...	21	0·241	0·410	0·169	1 : 1·426
B 3	With *A. christyi* ...	16	0·279	0·508	0·229	1 : 1·218
	Without *A. christyi* ...	12	0·220	0·323	0·103	1 : 2·136
B 3	With *A. cinereus* ...	9	0·187	0·352	0·165	1 : 1·133
	Without *A. cinereus* ...	19	0·285	0·465	0·180	1 : 1·583
B 5	With Anophelines ...	5	0·134	0·252	0·123	1 : 0·968
	Without Anophelines ...	33	0·151	0·307	0·156	

In Table I, B 1 to B 6 are places along the Getathuru River—a small stream running in a deep valley with sides well clothed in long grass, reeds, and native-grown maize and sugar-canes. Like all streams here it is subject to flooding during heavy rains and in very dry periods becomes reduced to a mere trickle with many pools.

B 3 is a place used by natives for domestic water. Banks are of small rocks and soil. In the bed are patches of lanky aquatic grasses, at the base of which Anophelines harboured when the water was low. This place is quite exposed.

B 5 was on the side of the river about 150 yards up in a wider section of the valley. Its earth banks are covered with native-grown sugar-cane and thick vegetation, which provide shade and shelter for fairly long periods of the day.

Of the 6 places chosen, B 3 appeared to be the most, and B 5 the least, attractive breeding-grounds. B 1 was much less used than the others.

The organic content of B 3 (Table I), as indicated by the oxygen absorbed, is higher than that of B 5 over the whole period. Moreover, in B 3 the samples positive to *A. costalis* and *A. christyi* are higher in organic content than those that contained no larvae.

For *A. cinereus*, on the contrary, the samples with larvae appeared to have less organic matter than those without.

In B 3 the ratio of organic and inorganic matter is slightly lower in waters positive to *A. costalis* than in waters negative to this species ; considerably higher in positive *A. christyi* and *A. cinereus* samples than in those that were negative. B 5 waters showed a ratio consistently high.

Table II deals with eight breeding-places along the lower section of Nairobi River, near Pumwani. In this portion the river produces a dense growth of papyrus in a swampy bed with no clear-cut channel. The gently sloping banks are covered

with grass and native vegetables, mostly sweet potatoes, and numerous small springs occur on the western slope. The river carries much filth and drainage throughout its course through Nairobi.

TABLE II

Breeding-place	Sample	Number	Average			Ratio of organic to inorganic
			After 15 minutes	After 4 hours	Differente	
Q 5	With *A. costalis* ...	22	0·706	1·009	0·303	1 : 2·330
	Without *A. costalis* ...	8	0·188	0·360	0·172	1 : 1·093
Q 5	With *A. christyi* ...	16	0·837	1·164	0·327	1 : 2·560
	Without *A. christyi* ...	14	0·259	0·460	0·201	1 : 1·289
Q 6	No Anophelines ...	42	0·178	0·311	0·133	1 : 1·338

Q 5 is water from a spring on the slope between the last houses of Pumwani and the stream. At the bottom of the slope stagnation occurs. Grass or vegetables occur around, and rubbish from the village is thrown out here indiscriminately. When the river is high during heavy rains its waters rise as far as the spring water of Q 5.

Q 6, a little higher up, is at the side of the water on the edge of the papyrus growth and actually shaded during part of the day by papyrus. All river fluctuations influence Q 6.

Q 5 samples positive to *A. costalis* and *A. christyi* showed a higher organic index than negative samples from the same source and considerably higher than the series from Q 6. Moreover, the ratio of organic to inorganic matter is very much lower in positive than in negative samples.

TABLE III

Breeding place	Sample	Number	Average			Ratio of organic to inorganic
			After 15 minutes	After 4 hours	Difference	
S 3	With *A. costalis* ...	8	0·695	1·132	0·437	1 : 1·590
	Without *A. costalis* ...	10	0·544	0·958	0·414	1 : 1·314
S 3	With *A. christyi* ...	7	0·572	0·945	0·373	1 : 1·534
	Without *A. christyi* ...	11	0·636	1·093	0·457	1 : 1·392
S 1	Without Anophelines ...	35	0·175	0·343	0·168	1 : 1·042

Table III deals with the Kirichwa River.

S 1 is a spot in the rocky bed of the river. During heavy rains the river is thoroughly flushed out; in dry periods it becomes a series of pools. At this spot the water contained no vegetation.

S 3 is about half a mile above S 1 with banks of earth and rock and, in periods of stagnation, with accumulations of gravelly sand in the bed. The river-bed is in a deep valley with grass and bush on its sides, subject to considerable "wash" during the rains.

S 3 attracted Anophelines throughout the period, but only on one occasion were they found in S 1.

The organic content of the water of S 3 was considerably higher than that of S 1.

Samples of S 3 containing *A. costalis* exhibited very slightly higher organic content than those without *costalis*; and waters with *A. christyi* were definitely lower in organic content than those without this species.

The ratio of the figures representing organic and inorganic matter is lower in positive *A. costalis* and *A. christyi* waters of S 3 than in negative waters, and still lower than the negative waters of S 1.

TABLE IV

Breeding-place	Sample	Number	Average			Ratio of organic to inorganic
			After 15 minutes	After 4 hours	Difference	
HO 26	With *A costalis* ...	6	0·720	1·156	0·436	1 1 650
	Without *A costalis* ...	10	0·774	1·138	0·364	1 2·126
HO 26	With *A christyi* ...	12	0·660	1·083	0·423	1 . 1·560
	Without *A. christyi* ...	4	1·037	1·330	0·293	1 : 3·539
HO 31	Without Anophelines ...	24	0·189	0·370	0·181	1 : 1·044

HO 15 to 32 are completely exposed borrow-pits along both sides of the Ngong Road, from which murrum has been obtained. They vary considerably in age and size, but otherwise they appear to be much alike. Nos. 32 and 31 are about 300 yards from 30, 29, 28, 27, 26 and 25, these latter being quite close together—in fact, 28 and 29 are joined at high water and 27 empties itself into 26.

During the period of observation murrum was again taken from nos. 29 and 27, so that these may be regarded as partly new. A newly made murrum pit is devoid of vegetation and organic accumulations. Neither 26 nor 31 was disturbed by digging during the period of observation, though some of the others were.

No. 26 is a large pit with considerable soil accumulations in its bed, and these produce patches of grass. The sides are fairly straight cut and bare except at the corners. The Anophelines were found mostly beneath the bank, near a grass patch on one edge of the pit. This pit appears to take a considerable amount of drainage from the surrounding grass places.

No. 31, about equal in size to no. 26, is rather shallower and at high water delivers a stream into the road. Its clay-like deposit has borne no vegetation during the period of observation.

Pit no. 28, similar to no. 26 and immediately opposite, has produced Anophelines to about the same extent as 26, whereas 29, adjoining, has produced none ; nor has 27, which adjoins 26. Now 27 has undergone excavation during the period, and this may account for the absence of Anophelines, but 29 has not, so that this explanation is not generally applicable.

The organic indices for waters with *A. costalis* and *A. christyi* are higher than those for negative waters from the same source (Table IV, HO 26) and very considerably higher than the figures for HO 31 during the period.

The ratio of organic to inorganic matter is very much higher for positive *A. costalis* and *A. christyi* samples than for negative samples, but very considerably lower than for the HO 31 series.

TABLE V

Breeding-place	Sample	Number	Average			Ratio of organic to inorganic
			After 15 minutes	After 4 hours	Difference	
G 2	With *A. costalis* ..	5	1 324	1 873	0 549	1 2·412
	Without *A. costalis* ..	12	0 323	0 561	0 238	1 1 357
G 2	With *A. christyi* ..	3	1 527	2·128	0·601	1 2·541
	Without *A. christyi* ..	14	0 423	0 694	0·271	1 1·561
G 1	Without Anophelines ...	26	0·178	0·333	0·155	1 1·148

Table V deals with breeding-places along the Ngong River in the section running along the edge of the plains. This river exhibits flooding and pooling in the same way as other local streams ; but the pools are more usually choked with coarse aquatic reeds and grass, and the pool water appears to be rather more filthy-looking than in most other places.

G 1, 2 and 3 were in the river itself, and 4 and 7 were in grassy excavations along the banks lower down.

Waters containing *A. costalis* and *A. christyi* (in G 2) exhibit a considerably higher organic index than waters with no Anophelines. G 1 produced Anopheline larvae on four occasions, on two of which the organic index had risen to very high levels ; on the remaining two occasions (November 1929) immature larvae only were found.

The ratio of organic and inorganic matter is lower in samples positive to *A. costalis* and *A. christyi* than in negative samples from the same source in G 2 and still lower than in the continuously negative G 1.

Suggestions from the Figures.

1. Waters producing the majority of Anophelines were those in which the O_2 values varied most during the period.

2. Except in the waters positive to *A. cinereus* in the B series and to *A. christyi* in the S series, the samples of water containing Anophelines show higher organic indices than those without. Particularly, it is noticeable that the series of samples in which very few or no Anophelines occurred show lower indices consistently.

3. With the exception of the S series and of the *A. costalis* and *A. cinereus* values in B 3, the ratio of organic to inorganic matter in waters producing Anophelines has been lower than in waters in which no Anophelines were found. This ratio is particularly high in waters that have been consistently without Anophelines.

4. Certain waters appear to be definitely and always attractive, others only partly so, and others still appear never to be used for breeding.

5. After a dry period it appears that heavy washing rains result in the addition of considerable quantities of organic matter and the organic index rises immediately. It falls as rapidly immediately afterwards.

STUDIES ON *AËDES* LARVAE IN SOUTH-WESTERN NIGERIA AND IN THE VICINITY OF KANO.*

By HENRY W. KUMM, M.D., D.T.M. & H., D.P.H.

Introduction.

Many of the *Aëdes* larvae commonly met with in Nigeria have been described by Ingram & Macfie, who have made extensive studies on the Gold Coast. Wesché described larvae of seven species of *Aëdes* that he studied in Lagos in 1910.[12] In 1912 Edwards published keys to the then known larvae of the African CULICINAE,[1] but many of the species of *Aëdes* that are plentiful in this area are not included in Edwards' key. Therefore it was thought that an additional comparative study would be of value.

The larvae dealt with in this paper by no means represent all the species that can be found in this area. They merely include the commoner ones in the vicinities of Kano, Ibadan, and Lagos, and some additional specimens of species found in Nigeria, which were lent by Mr. F. W. Edwards, of the British Museum, and Dr. V. B. Wigglesworth, of the London School of Hygiene and Tropical Medicine. The sources from which the specimens collected in South-western Nigeria were obtained include the following :—

Water-pots inside and outside houses ...	*Aëdes aegypti*
Rock-holes	,, *vittatus*
(in Kano, *A. vittatus* was often found in water-pots also)	
Tree-holes	
(1) Ordinary trees including the flamboyant (*Poinciana regia*)	*Aëdes longipalpis*
	,, *apicoargenteus*
	,, *luteocephalus*
	,, *africanus*
	,, *simpsoni*
	,, *stokesi*
	,, *wellmani*
	,, *aegypti*
(*Aëdes metallicus* was found in tree-holes in Kano but not in Ibadan)	
(2) Bamboo stumps	*Aëdes dendrophilus*
	,, *simulans*
	,, *africanus*
	,, *longipalpis*
	,, *apicoargenteus*
	,, *luteocephalus*
	,, *kummi*
	,, *argenteoventralis* var. *dunni*
Crab-holes	*Aëdes irritans*
	,, *nigricephalus*
	,, *sudanensis*
Pools of muddy water at Kano	*Aëdes hirsutus*
	,, *vittatus*

* The studies and observations on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation.

These specimens were all larval skins. In each case the adult was bred out, and the corresponding larval pelt mounted in balsam on a slide.

The comparisons and the larval key are based on the following numbers of mounted specimens studied :—

Aëdes	*apicoargenteus*	65
,,	*longipalpis*	58
,,	*luteocephalus*	30
,,	*argenteoventralis* var. *dunni*	24
,,	*kummi*	15
,,	*hirsutus*	15
,,	*unilineatus*	15
,,	*stokesi*	14
,,	*irritans*	13
,,	*africanus*	12
,,	*vittatus*	12
,,	*aegypti*	10
,,	*dendrophilus*	7
,,	*metallicus*	5
,,	*nigricephalus*	5
,,	*sudanensis*	5
,,	*domesticus*	4
,,	*simulans*	3
,,	(*Banksinella*) *lineatopennis*	3
,,	*simpsoni*	2
,,	*nigeriensis*	2
,,	(*Banksinella*) *punctocostalis*	2
,,	*wellmani*	1
,,	*abnormalis*	1

Descriptions of the larvae of *hirsutus*, *simulans* and *kummi* were not found in the literature, so these are given below. We were unable to differentiate the larvae of *kummi* and *argenteoventralis* var. *dunni*,[4] although the adults can be readily distinguished from each other. *A. simulans* and *kummi* were found breeding in bamboo stumps in the vicinity of Ibadan, and *hirsutus* was very plentiful in pools of muddy water at Kano in June 1929.

No attempt is made to give a key such as would enable the investigator to tell at first glance whether the larva belongs to the genus *Aëdes* or to some other genus. A key of that sort would have to be made by someone having a much greater amount of material for study than was at our disposal. But, in general, we were able to distinguish *Aëdes* larvae from *Culex* larvae by their movements when alive, by the fact that as a rule *Culex* larvae have a longer siphon than *Aëdes* larvae, and finally because *Aëdes* have only one pair of ventral tufts on the siphon, while *Culex* larvae have several tufts. The *Megarhinus* larvae found in tree-holes were distinctive because of their size, and the *Eretmopodites* larvae inhabiting bamboo stumps were differentiated by the absence of a ventral brush on the anal segment.

In general the terminology used in the key is the same as that of Ingram & Macfie. However, the terms " pecten teeth " and " comb teeth " are used instead of " pecten spines " and " comb spines." In *Aëdes* larvae there is frequently a hair-tuft at the lateral edge of the chitinous plate of the anal segment. Ingram & Macfie, in describing *A. apicoargenteus*,[10] referred to this tuft as " the hair on each side of the anal segment near the middle of the posterior margin." For the sake of brevity we have referred to this tuft as " the lateral tuft." In a careful study of 65 mounted specimens of *apicoargenteus* we found that the lateral tuft was composed of a single hair only. This appeared to be a constant character and is used as such in the key.

Grateful acknowledgment is made to Mr. F. W. Edwards for the use of preparations of *A. sudanensis* and *lineatopennis*; to Dr. V. B. Wigglesworth for *unilineatus, punctocostalis*, and *abnormalis*; to the London School of Hygiene and Tropical Medicine for *domesticus, nigeriensis*, and *wellmani*; and to Mr. A. Pretious, European sanitary inspector at Kano, who kindly sent the larvae of *hirsutus* and *metallicus* used in this study. Identifications of adult mosquitos were made through the kindness of Mr. C. B. Philip, Dr. P. A. Buxton, Dr. V. B. Wigglesworth, and Mr. F. W. Edwards.

Key to the Larvae of the commoner Species of Aëdes *in Nigeria.*

1. Less than 15 teeth in each comb (except *abnormalis* which has 24–30 comb teeth) 2
   More than 35 teeth in each comb 19

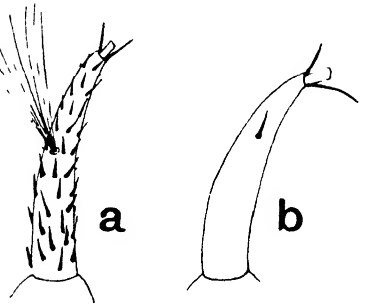

Fig. 1. Antenna of: (*a*) *Aëdes nigeriensis*; (*b*) *A. aegypti*.

2. Shaft of each antenna with one hair-tuft only 3
   Entire shaft of antennae covered with minute spicules or hairs in addition to the hair tuft 12

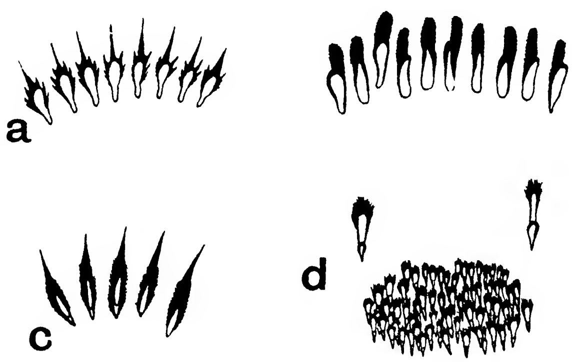

Fig. 2. Comb teeth of: (*a*) *Aëdes aegypti*, the teeth with prominent barbs; (*b*) *A. luteocephalus*, the teeth with very fine barbs (so-called "simple comb teeth"), in this case so fine that they are visible only under very high magnification.
Comb of: (*c*) *Aëdes domesticus*, with five teeth only; (*d*) *A. longipalpis*, with 60–75 teeth.

Comb teeth, 7–10 in number, each with numerous prominent barbs; abdominal hair-tufts not large 4
Comb teeth without barbs or with only fine barbs (except *metallicus* and *unilineatus*, which however, in addition to having some barbed comb teeth, have many prominent and large abdominal hair tufts) 5

4. Pecten teeth, 9–16 in number, usually in a continuous row ... *aegypti*
Pecten teeth, 5–10 in number, often with one tooth detached towards the apex of the siphon beyond the hair-tuft ... ... *simpsoni*

5. Posterior tuft on siphon with 3–7 hairs; pecten teeth barbed on one side, usually with one tooth detached towards the apex of the siphon *vittatus*
Larva not possessing all these characters simultaneously 6

6. Single lateral hair only on each side of the anal segment ... *apicoargenteus*
Tuft of 2–5 lateral hairs on each side of the anal segment 7

7. Majority of pecten teeth without barbs, or only with exceedingly minute barbs (those of *argenteoventralis* variety *dunni* and of *Aëdes kummi* usually have very fine serrations towards the tip) 8
Pecten teeth with prominent lateral barbs 9

8. Pecten with one tooth detached towards apex of siphon; siphon short, thick, and dark in colour ... ... *dendrophilus*
Pecten teeth in a continuous row; siphon longer and light in colour *argenteoventralis* var. *dunni* and *kummi*
(The larvae of *argenteoventralis* var. *dunni* and *kummi* are indistinguishable one from the other.)

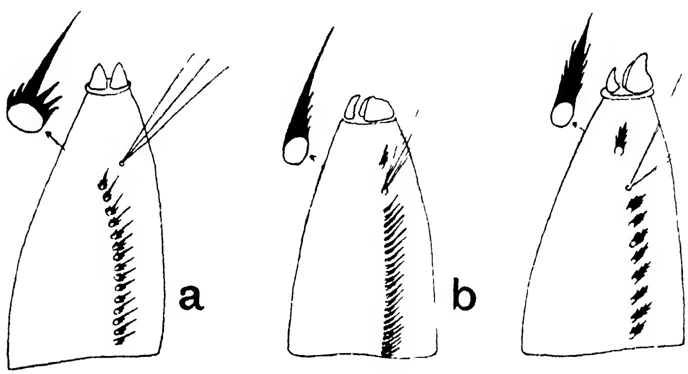

Fig. 3. Siphon of: (*a*) *Aëdes aegypti*; (*b*) *A. vittatus*; (*c*) *A. simpsoni*, showing structure of the pecten and posterior hair-tuft

9. Pecten teeth with a single barb only; abdominal hair-tufts not very prominent *africanus*
Pecten teeth with two or more barbs; large and prominent hair-tufts all over the abdomen 10

10. Usually a single hair only in the tuft beyond the pecten ... ... *luteocephalus*
The posterior tuft composed of 2–4 hairs; some of the comb teeth barbed 11

11. Prominent hook-like spines on the ventro-lateral aspect of the thorax and arising from chitinous plaques ... ... *metallicus*
These spines small or entirely absent ... ... *unilineatus*

12. Comb teeth, 5–6 in number ... ... *domesticus*
Comb teeth, 7 or more in number 13

13. Banded abdomen (4th, 7th, and 8th segments light in colour, with remainder dark) ... ... *punctocostalis*
Abdominal segments uniform in colour 14

14. Comb teeth, 24–30 in number; very long and slender antennae ... *abnormalis*
Comb teeth, 7–15 in number; antennae of normal length 15

15. Pecten with last two or three teeth detached towards the apex of the siphon, one usually beyond the hair-tuft 16
Pecten with 14–22 teeth in a continuous row 18

16. Majority of pecten teeth with 3–5 prominent barbs (except the two detached ones which usually have no prominent barbs, and sometimes none at all) *hirsutus*
Majority of pecten teeth with 1 or 2 barbs only 17

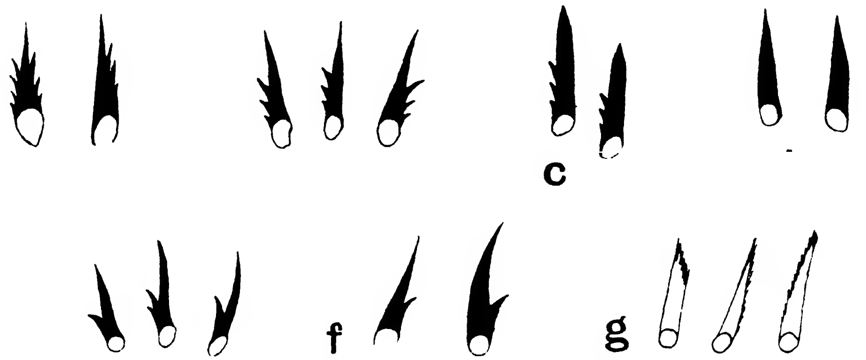

Fig 4 Pecten teeth of (*a*) *Aedes luteocephalus*, (*b*) *A stokesi*, and (*c*) *A longipalpis*, showing several prominent barbs, (*d*) *A dendrophilus*, showing absence of barbs, (*e*) *A wellmani*, and (*f*) *A africanus* showing a single prominent barb, (*g*) *A argenteoventralis* var *dunni*, showing terminal serrations

17. Median frontal hairs single ... ... *nigeriensis*
Median frontal hairs multiple ... ... *lineatopennis*

18 Comb teeth, 7–8 in number ; pecten teeth usually with one barb only *wellmani*
Comb teeth, 9–14 in number ; pecten teeth with two or more barbs *stokesi*

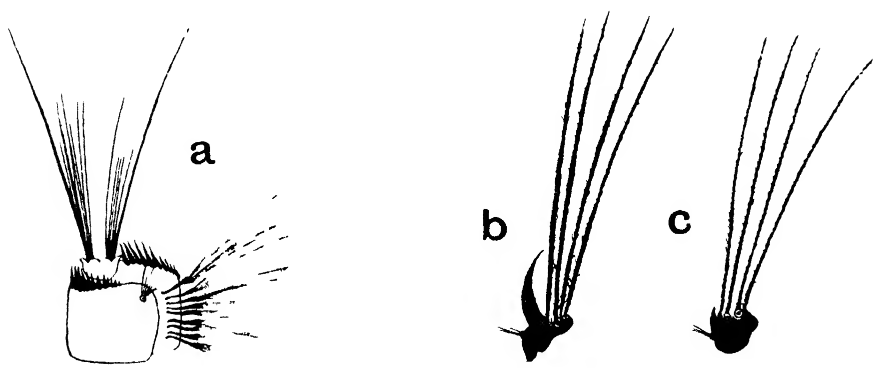

Fig 5 (*a*) Anal segments of *Aëdes longipalpis*, showing "anal teeth" Thoracic chitinous plaque of . (*b*) *A metallicus*, with its large hook-like spine, (*c*) *A unilineatus*.

19. Anal segment with scales resembling teeth on both sides of the dorsal hair-tuft ; pecten teeth with several prominent barbs ... ... *longipalpis*
No anal teeth ; pecten teeth with only one or two barbs 20

20. Anal segment with lateral hair-tuft of 1–3 large hairs ... ... *simulans*
Lateral anal hair-tuft usually very small and with one hair only... ... 21

21. Last tooth of pecten detached towards apex of siphon ; long anal papillae ... *sudanensis*
Pecten teeth in a continuous row ; short anal papillae 22

22. Posterior tuft of 2–4 hairs ... ... *irritans*
Posterior tuft of 1 hair only ... ... *nigricephalus*

Comparison of Characters of Larvae of the commoner Species of Aëdes *in Nigeria.*

Name of species	Number of comb teeth	Number of pecten teeth	Number of hairs in posterior tuft on siphon	Number of hairs in lateral tuft on anal segment
Aëdes abnormalis	24–30	24–26	5	2
,, *aegypti*	7–10	9–16	2–3	2
,, *africanus*	8–11	10–20	2	2
,, *apicoargenteus* ...	7–14	9–16	2	1
,, *argenteoventralis* var. *dunni*	7–16	8–16	1–3	2
,, *dendrophilus* ...	8–11	9–15	2	2
,, *domesticus*	5–6	14–16	5–9	1
,, *hirsutus*	7–10	14–22	2–3	1
,, *irritans*	Over 35	15–20	2–4	1
,, *kummi*	7–16	8–16	1–3	2
,, *lineatopennis* ...	7–9	14–18	4–5	1–2
,, *longipalpis* ...	Over 35	15–22	3–7	—
,, *luteocephalus* ...	8–11	10–18	1 (very occasionally 2)	2–3
,, *metallicus*	6–8	8–13	2–4	3–5
,, *nigeriensis*	9–12	17–18	5	—
,, *nigricephalus* ...	Over 35	12–22	1	1
,, *punctocostalis* ...	8	14–15	1–2	2
,, *simpsoni*	7–10	5–10	3	2
,, *simulans*	Over 35	15–22	3–4	1–3
,, *stokesi*	9–14	14–22	5–8	2–3
,, *sudanensis*	Over 35	15–18	1	1
,, *unilineatus*	4–8	6–12	2–5	3–5
,, *vittatus*	5–8	16–26	3–7	—
,, *wellmani*	7–8	16–20	4–5	1

Descriptions of Larvae.

Aëdes hirsutus (fig. 6).*

The larva is relatively large in size and light in colour.

Head broad ; median frontal hairs multiple ; broad triangular mental plate. *Antennae* variable in length and shape ; covered with numerous fine spicules or hairs ; less than half-way down the antenna from its base is a tuft of 5–8 fairly long hairs. *Thorax* with large lateral hair-tufts, but median tufts almost absent. *Abdomen* with small lateral tufts and practically no other tufts at all. *Comb* : teeth light in colour and 7–10 in number ; they are very prominently barbed, even more so than those of *A. aegypti*. *Siphon* more than twice as long as broad, light in colour ; posterior tuft on siphon of 4–8 fine hairs. *Pecten* with 14–22 teeth barbed characteristically ; the last two teeth detached from the others towards the apex of the siphon, larger than the others and barbed in a different fashion. *Anal segment* :

* [The author informs us that since this was written he has seen a description of the larva of *A. hirsutus* by Ingram & De Meillon (Publ. S. Afr. Inst. Med. Res., iv, no. 23, Jan. 1929, pp. 83–170) ; but as his own description gives some additional details, it has been allowed to stand here.—*Ed.*]

dorsal brush arising from a chitinous plaque ; ventral brush large and well formed ; anal papillae long, pointed, and all of about the same length ; a single very fine lateral hair is occasionally seen.

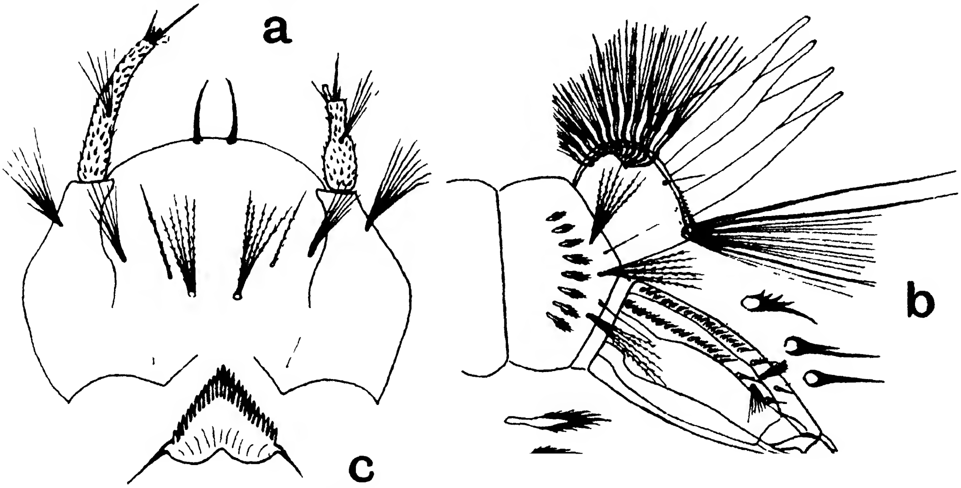

Fig 6. Larva of *Aedes hirsutus*. *a*, head, *b*, terminal segments of abdomen, *c*, mental plate

Aëdes simulans (fig 7)

Small in size and relatively dark in colour.

Head broad ; median frontal hairs well developed and multiple ; mental plate small in size and narrow laterally. *Antennae* medium in length and dark in colour ;

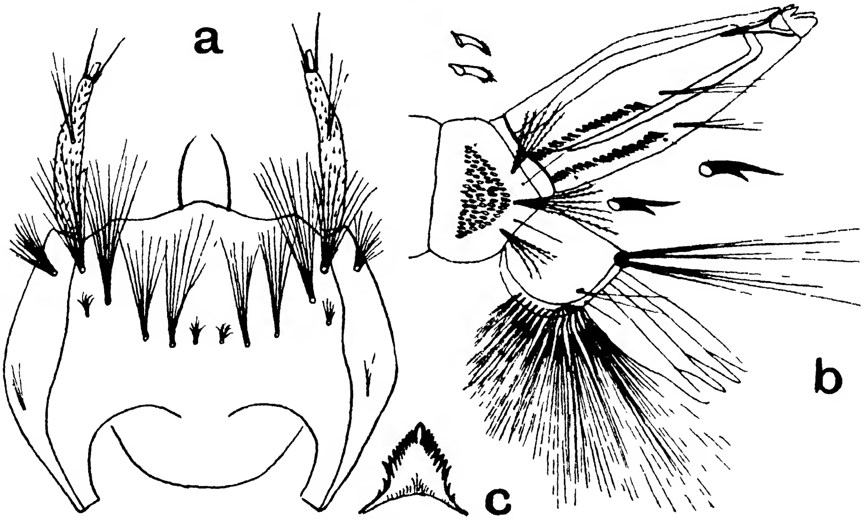

Fig. 7. Larva of *Aedes simulans*. *a*, head *b*, terminal segments of abdomen, *c* mental plate

entire shaft covered with fine spicules or hairs ; the antennal tuft of 3–5 strong hairs is situated more than half-way down the antenna from its base. *Thorax* with large multiple lateral hair-tufts arising from small chitinous plaques ; median tufts much smaller but also multiple. *Abdomen* with lateral tufts of one or two fairly large hairs ;

median tufts small. *Comb* : teeth light in colour and 40–65 in number, finely barbed. *Siphon* dark in colour, about three times as long as the diameter of its base ; posterior tuft of 3–4 hairs situated about half-way down the shaft. *Pecten* : teeth dark in colour and 15–22 in number ; teeth in a continuous row, the majority having a single prominent lateral barb. *Anal segment* with dorsal tuft consisting of a number of large hairs arising from a chitinous plaque ; ventral brush well developed ; lateral tuft of 1–3 large hairs readily seen ; anal papillae medium in size and slender though with a rounded tip.

Aëdes kummi (fig. 8).

The larva is medium in size and light in colour, often actually white when taken from bamboo stumps.

Head broad ; median frontal hairs usually single ; mental plate broadly triangular and much like that of *A. hirsutus*. *Antennae* light in colour and fairly short ; smooth

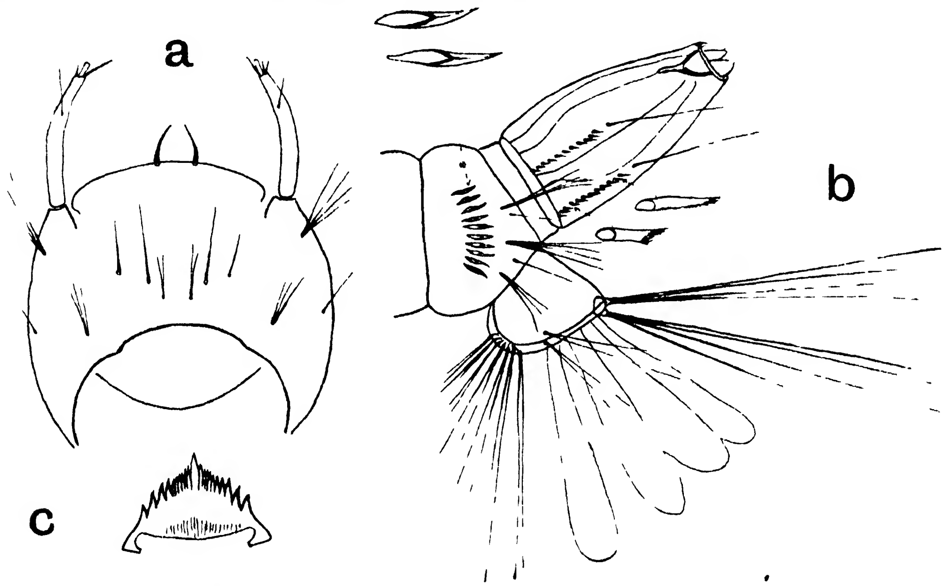

Fig 8. Larva of *Aëdes kummi* *a*, head , *b*, terminal segments of abdomen ; *c*, mental plate

and without spicules on the shaft except for a single short hair in the place of the usual antennal tuft ; this hair is situated quite near the apex of the antenna (more than two-thirds of the way down the shaft from its base). *Thorax* with large multiple lateral hair-tufts arising from small chitinous plaques ; small median tufts of two or more hairs each. *Abdomen* more hairy in the posterior segments ; lateral tufts large, consisting of branched hairs ; median tufts smaller. *Comb* : teeth light in colour and 7–16 in number, usually not barbed but occasionally with minute barbs at the base of the tooth. *Siphon* short and light in colour, less than twice as long as the diameter of its base ; a posterior tuft of usually one and occasionally two or three subplumose hairs. *Pecten* : teeth light in colour and 8–16 in number, in a continuous row ; the teeth are not barbed as in most other *Aëdes* larvae, but many of them are serrated at the tip and quite without barbs laterally. *Anal segment* with well-developed dorsal tufts arising from a chitinous plaque ; ventral brush quite small ; lateral tufts of two large hairs each ; anal papillae large, rounded at the tip, and all of about the same length.

List of Mosquitos collected in other Localities in Nigeria, and identified by Mr. F. W. Edwards, of the British Museum.

ADAMAWA PROVINCE.

(1) Jalingo ... *Aëdes aegypti, A. argenteopunctatus.*
(2) Lau ... *Culex univittatus.*
(3) Yola ... *Aëdes aegypti, A. vittatus, Culex univittatus, Anopheles gambiae, A. rufipes.*

BENUE PROVINCE.

(1) Donga ... *Aëdes aegypti, Culex ager, C. univittatus.*
(2) Ibi ... *Aëdes vittatus, Culex duttoni, C. laurenti, C. univittatus, C. perfuscus, Anopheles gambiae, A. funestus, Taeniorhynchus africanus.*
(3) Wukari ... *Anopheles gambiae, Aëdomyia africana, Culex univittatus, Mimomyia splendens.*

KANO PROVINCE.

(1) Kano ... *Aëdes aegypti, A. vittatus, A. hirsutus, A. furcifer, A. rhecter, A. metallicus, Anopheles gambiae, A. rufipes, Culex univittatus, C. duttoni, C. decens, C. nebulosus.*

ZARIA PROVINCE.

(1) Katsina ... *Aëdes aegypti, A. vittatus, A. hirsutus, Anopheles gambiae, Culex decens.*

OYO PROVINCE.

(1) Ibadan ... *Aëdes aegypti, A. vittatus, A. stokesi, A. luteocephalus, A. africanus, A. simpsoni, A. apicoargenteus, A. longipalpis, A. dendrophilus, A. simulans, A. sudanensis, A. kummi, A. argenteoventralis* var. *dunni, A. wellmani, Aëdomyia africana, Taeniorhynchus africanus, Theobaldia fraseri, Eretmopodites chrysogaster, Ficalbia malfeyti, Mimomyia mimomyiaformis, Anopheles mauritianus, A. gambiae, A. funestus, Culex nebulosus, C. tigripes, C. rima, C. duttoni, C. pruina, C. horridus, C. albiventris, C. consimilis, Megarhinus brevipalpis, M. aeneus.*

Note.—The following are synonyms for some of the species listed above :—

Aëdes vittatus is also called *A. sugens.*
Aëdes stokesi is also called *A. apicoannulatus.*
Anopheles gambiae is also called *A. costalis.*
Culex rima is also called *C. insignis.*

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BRACONIDAE: NOTES AND NEW SPECIES.

By D. S. Wilkinson,
Entomologist, Imperial Institute of Entomology.

Rhaconotus mahensis, sp. n.

♀♂. Black; scape and all legs red testaceous; ovipositor bright red; flagellum red-brown, possibly rather darker at apex; wings hyaline, the setae with a distinctly fulvous tinge, and the stigma hyaline (at least not darkened).

♀♂. The integument is not coriaceous throughout, and is only sparsely clothed with setae (except on the flagellum and possibly the legs). *Head* smooth and highly shining, not coriaceous, impunctate, the vertex and occiput almost entirely devoid of setae; antennae longer than head, thorax, and abdomen together; flagellar joints in ♀ 29–33, in ♂ 26–28. *Thorax*: mesonotum dully shining, coriaceous; the notauli well marked, joining slightly before reaching the posterior margin of the mesonotum; propodeon with five longitudinal carinae, one in the middle and two on each side, these latter rather more closely placed to each other than to the median carina; this median carina is discernible as such only in the basal half of the propodeon, thereafter becoming lost amongst the reticulate wrinkles with which the apical half of the propodeon abounds; the lateral carinae, on the other hand, are discernible more or less throughout their length, particularly the inner pair which can generally be traced to the median apex of the propodeon where they join each other; the integument of the basal half of the propodeon coriaceous on each side of the median carina as far as the first lateral carina, thereafter wrinkled as in the apical half. *Wings* with the recurrent received distinctly into the 2nd cubital; nervulus very slightly postfurcal; radial cell reaching apex of wing; 2nd abscissa of radial vein about five times, and the 3rd abscissa about seven times, as long as their 1st abscissa. *Legs*: all femora with a noticeable tumescence on the antero-dorsal surface at apex of basal third; the anterior tibiae anteriorly with a row of minute spines. *Abdomen*: 1st tergite completely and strongly longitudinally carinate; 2nd tergite of ♀ longitudinally carinate in basal two-thirds, with at apex of median third a pseudosuture, which is shallow and broad, and with the apical third virtually smooth, in the ♂ the pseudosuture at base of apical fourth, and with the apical fourth inclined to be minutely wrinkled; 3rd tergite of ♀ longitudinally striate in basal half to two-thirds, of ♂ in basal three-fourths, otherwise smooth; 4th tergite in ♀ faintly longitudinally aciculated in basal half, in ♂ striate in basal three-fourths, otherwise smooth; 5th tergite of ♀ entirely smooth, of ♂ faintly longitudinally aciculated in basal half, otherwise smooth; succeeding tergites of ♂ smooth; 2nd and 3rd sutures strongly crenulate and virtually straight; ovipositor sheaths long, extending beyond apex of abdomen for a length definitely rather greater than the combined lengths of the 2nd, 3rd, 4th and 5th tergites.

Length: ♀, 4·0–5·0 mm.; ♂, about 3·5–4·0 mm.

Seychelles Is.: Mahé, 4 ♀♀, 3 ♂♂. All from the high endemic forests: between Trois Frères and Morne Seychellois, 1,500–2,000 ft., xii.1908 and i.1909; Mare aux Cochons district, 1,000–2,000 ft., i–ii.1909; and Cascade Estate, 1,000–2,000 ft., ii.1909 (***Hugh Scott***).

Type deposited in the British Museum.

Host unknown.

Rhaconotus mahensis, on account of its coloration and smooth head, is immediately separable from other species described in this genus. It will not run in my key (Bull.

Ent. Research, xviii, 1927, p. 37), since the 2nd suture is straight and the wings are without brown patches of infuscation, in this respect agreeing with *R. oryzae*, Wilkn. (Bull. Ent. Research, xx, 1929, p. 205).

Apanteles plutellae, sp. n.

♀♂. Extremely close to *Apanteles maculitarsis*, Cam., but differing therefrom in the following characters at least :—In the punctation of the hind coxae which, both basally above and otherwise where occurring, is minute (degree 1–2), closely placed, and distinct throughout, as opposed to that in *maculitarsis* which basally above is coarsely indefinite but minute elsewhere ; in its 2nd tergite, which is slightly emarginate and longer, and whose noticeably decurved discal sulci are very definitely finer and more lightly impressed, than in *maculitarsis* ; and in the hind femora, which are longer and rather more cylindrical.

Length, 3 mm.

JAVA : 5 ♀♀, 2 ♂♂, iii.1929 (*Dr. S. Leefmans*).

Type deposited in the British Museum.

Host. This species is recorded to have been bred from the Microlepidopteron, *Plutella maculipennis*, Curtis.

Cocoons unknown.

A revision of the *vitripennis* subgroup of the genus *Apanteles*, to which subgroup *maculitarsis* and this new species belong, is in active course of preparation and will shortly be published, and the description of *plutellae* is presented at this time only because the identification of this series was particularly required by the collector at an early date.

Apanteles picipes, Bouché 1834.

FRANCE : neighbourhood of Paris, 1 ♀, 1 ♂, undated (*A. M. Vance*).

Host. This material was sent to me for identification by Mr. H. L. Parker, of the European Parasite Laboratory, Hyères. Bred from the Pyraustine, *Pyrausta nubilalis*, it agrees perfectly with material in the Lyle collection bred from the Pyraustine, *Pionea forficalis*, of which latter host Marshall, in his monograph, records Bouché's species to be a solitary parasite.

Apanteles mycetophilus, sp. n.

♀♂. Black ; the majority of the basal two-thirds of the scape, the costal veins more or less, the anterior legs (except their coxae), hind trochanters and trochantines, hind femora, hind tibiae basally, and basal ventrites, red testaceous ; hind tibiae apically, and hind tarsi, decidedly browned ; palpi and tibial spurs pale ; wings hyaline, remaining wing-veins more or less brown, the stigma dark brown to black.

♀♂. *Head* : face with minute punctation (degree 2) which is more or less regular and close ; clypeus not differentiated ; facial depressions rather nearer to apex of clypeus than to the eyes ; posterior ocelli nearer to each other than to the eyes. *Thorax* : mesonotum shining, in posterior two-thirds with regular, well-spaced, minute punctation (degree 2), anteriorly with the punctures closer and stronger (degree 3) ; disc of scutellum smooth and shining, with very sparse, minute punctation (degree 1) ; propodeon with basal two-thirds smooth save for some sparsely placed, well-marked punctation (degree 3), the areola indicated only by a flat somewhat depressed area devoid of punctures, with apical third with numerous short, fairly strong carinae which radiate all round from the median semi-circular excision of the apical margin.

Wings : 1st abscissa of radial 1·33 times as long as the recurrent, weakly and evenly rounded, and its point of junction with the straight transverse cubital hard to determine exactly, longer than the transverse cubital, the length of which latter is about equal to the breadth of the stigma ; apical portion of 1st abscissa of cubital equal to the pigmented portion of the 2nd abscissa, longer than the upper portion of the basal vein, half the length of the 1st abscissa of the radial ; stigma considerably shorter than metacarp. *Legs* : hind coxae above, and on outer faces, in the greater part smooth with some minute punctation (degree 1), except for a group of rather stronger punctures basally above ; the hind tibial spurs subequal, the longer spur rather less than half the length of the basal joint of the hind tarsus. *Abdomen* : 1st tergite shining, smooth in basal half, punctate (degree 3) in apical half, at extreme apex with a short, oblique, fairly deep impression on each side of a smooth median area, with the sides almost straight, being only slightly angled in the middle and thus only slightly more strongly converging in the apical half, with basal breadth about 1·4 times apical breadth, and median length fully 1·5 times basal breadth, and the apex decidedly emarginate ; 2nd tergite with only some minute punctation, strongly transverse, with apical breadth fully four times median length in ♀ and fully three times in ♂, the apex more or less evenly and weakly rounded ; 3rd tergite smooth save for the usual minute punctation (as are the succeeding tergites), about 1·4 times as long as the 2nd ; ovipositor sheaths fully as long as the hind tarsus.

Length, 3·0–3·5 mm.

INDIA : Dandeli, N. Kanara, Bombay, 2 ♀♀, 16 iv.1930 (*type*), 19.v.1930, 1 ♂, 16.iv.1930 (*B. M. Bhatia*).

Type deposited in the British Museum.

Host. These specimens are labelled " *ex* Fungus."

Cocoons unknown.

Apanteles mycetophilus is very close to *A. calycinae*, Wilkn ; the differences in the colour of the scape and of the stigma, however, are sufficient readily to separate the two species, and the relative lengths of the spurs of the hind tibiae, which in *calycinae* are not subequal, together with the shape of the ovipositor, are morphological characters that may be cited in substantiation of the colour differences. The ovipositor in *calycinae* is weakly and regularly decurved virtually throughout its length ; that in *mycetophilus* is nearly straight in the basal half, but strongly decurved apically.

The single male is remarkable on account of some abnormal venation. The basal portion of the 1st abscissa of the cubital of the right fore wing is slightly angled at about its median point and from here throws off a vein, which, joining the lower portion of the basal vein above its middle, divides it into three portions and forms a new cell ; the median of these three portions of the basal vein is definitely greater than the upper portion. In the left fore wing, however, the basal half of the basal portion of the 1st abscissa of the cubital is entirely wanting (save for a very slight indication on the basal vein), and is represented solely by the abnormal vein.

Apanteles salutifer, sp. n.

♀. Black ; the anterior legs (except coxae, trochanters, and trochantines), hind femora, hind tibiae (except extreme apex), basal joint of hind tarsus in basal half, red testaceous ; hind tarsi otherwise, and extreme apex of hind tibiae, browned : palpi and tibial spurs pale ; wings hyaline ; the stigma uniformly opaque, brown, as is the metacarp ; wing-veins more or less brown, paler to colourless towards and at base of wing, the costal veins approaching testaceous.

♂. Agrees with the above description of the colour of the female except as follows :—Middle femora slightly darkened at extreme base ; hind femora darkened at apex, sometimes strongly darkened in both basal and apical fourth or third ; hind tibiae darkened in apical third, occasionally strongly so.

♀♂. *Head* : face and clypeus with close, even, strong but shallow punctation (degree 3–4), the clypeus somewhat raised and thus to some extent differentiated ; facial depressions rather nearer to apex of clypeus than to eyes ; frontal orbits, excavated areas immediately above insertion of antennae, and to some extent the frons, noticeably striate ; vertex minutely rugose ; occiput rugose and rugoso-striate ; the posterior ocelli nearer to each other than to the eyes. *Thorax* : mesonotum with strong very close punctation (degree 4) along the lines of the notauli, these latter posteriorly occupying the median half of the mesonotum and striato-punctate, the punctation of the mesonotum otherwise strong and close (degree 3–4) ; disc of scutellum with some indefinite punctation, particularly the sides ; propodeon in the areola, and also posteriorly to the costulae, shining and more or less completely smooth, anteriorly to the costulae on each side of the areola dull and more or less rugose ; the carinae of the areola and costulae strong ; costulae in the males rather more strongly oblique than in the females ; the areola complete, right across at extreme base (which corresponds with the extreme base of the propodeon) with a well-marked transverse carina, the sides in the basal half of the areola evenly diverging to the broadest point (which is at the point of emission of the costulae), then converging and V-shaped in apical half ; there is exhibited in the areola in various degrees of completeness, but never completely formed in the females, a transverse carina occurring more or less opposite to, or slightly basally from, the junction of the costulae, and thus forming a basal area more or less definitely separated from the areola proper. *Wings* : breadth of stigma three-fourths length of 1st abscissa of radial, 1·5 times length of transverse cubital, this latter shorter than the recurrent but only just shorter than the apical portion of the 1st abscissa of the cubital ; pigmented portion of the 2nd abscissa of the cubital short, shorter than upper portion of basal vein ; stigma shorter than metacarp ; 1st abscissa of radial slightly rounded (concavity basad), and the transverse cubital straight to very slightly rounded (convexity basad), usually with a knob at their point of junction. *Legs* : hind coxae above in basal half with close punctation, almost rugose, apically to some extent striate, on outer faces highly shining and virtually impunctate (or at most with only exceedingly minute punctures) ; the longer hind tibial spur just a little more than half, and the shorter spur just a little more than a third, the length of the basal joint of the hind tarsus. *Abdomen* : 1st tergite basally excavate and smooth save for some striation along the sides, medianly with a strong rugose tumescence on the posterior face of which is an oval, somewhat impressed and smooth area, this area normally conjoining with a highly shining and smooth area which occupies the median third of the extreme apex of the tergite, this latter area rendered prominent by a deep punctiform impression on each side, the tergite with sides more or less parallel, slightly converging in apical fourth, in the ♀ with greatest breadth about one-third median length (18 : 56), in the ♂ five-eighths, the apex of the tergite in both sexes truncate, or very slightly emarginate, the apical angles not rounded ; 2nd tergite, as the succeeding tergites, smooth save for the usual minute punctures, its base parallel with apex, laterally with well-marked, diverging, nearly straight sulci, with its median length half its basal breadth, about one-third its apical breadth, and half median length of 3rd tergite (8 : 16 : 24 : 16) ; 2nd suture obsolete ; ovipositor sheaths considerably longer than hind tarsi ; ovipositor very slightly, evenly decurved ; hypopygium membranously acute.

Length : ♀ 3 mm., ♂ 2·5–3·0 mm.

SIAM : Bangkok, 1 ♀ (*type*), 4 ♂♂, 1.i.1929, 2 ♀♀, 4 ♂♂, 1.i.1930 (*W. R. S. Ladell*). *Type* deposited in the British Museum.

Host unknown: the first series is numbered B.C. 355, and is recorded on a caterpillar feeding on *Sandoricum indicum*; the second series is numbered B.C. 353.

Cocoons unknown.

On account of the red testaceous hind femora of the female, the black scape, tegulae and hind coxae, together with the uniformly opaque stigma and smooth 2nd tergite, *A. salutifer* runs in my revised key to *prodeniae*, Vier., from which it is easily separable on the length of the ovipositor sheaths, and on the sculpturing of the frontal orbits and hind coxae.

Apanteles xanthostigmus, Haliday 1834.

The type of this species has been lost. Mr. Stelfox, who has been so good as to search the Haliday collection on my behalf, writes with regard to it that very few of the MICROGASTERINAE bear labels, and that amongst these *xanthostigmus* does not occur. He has also written to me to the effect that about a year ago he accidentally came across a statement in some old volume of the "Entomologist" saying that "Haliday's types" were lost through the foundering of a steamer in the Bristol Channel.

In the Marshall collection in the British Museum, however, is a specimen, a female, dated 2.ix.1884, and labelled "*xanthostigmus*, Hal.," that agrees perfectly both with Marshall's and with Reinhard's redescription of the species; this specimen I am making the neotype.

The Lyle collection, now in the British Museum, contains a series of ten specimens that, with one exception, agree perfectly with the neotype. In my opinion, however, it is far from certain what species Szépligeti had before him when he named an *Apanteles* for Silvestri and for Sarra; Silvestri's re-description of this species (Boll. Lab. Zool. Portici, ii, 1908, p. 149, and see x, 1915–16, p. 64) agrees well enough with what we understand to be *xanthostigmus*, but it definitely does not agree with his illustration. With regard to Faure & Alabouvette's record, see my notes under *Apanteles anarsiae*, which follow.

Apanteles anarsiae, Faure & Alab.

Apanteles xanthostigmus, Haliday, var. *anarsiae*, Faure & Alabouvette, Rev. Zool. agr. et app., xxiii, 1924, p. 283.

This species is known to me from 1 ♀, 1 ♂, vii.1930, Alps Maritimes, France, bred from the Tineid, *Anarsia lineatella*, Zell., 1 ♀, 1 ♂, 15.viii.1930, Andora, Italy, bred from the Tortricid, *Cydia* (*Laspeyresia*) *molesta*, Busck, these four having been received from G. J. Haeussler for identification, and 1 ♀, 1 ♂ that are in Dr. Ferrière's collection. These two latter had been forwarded to him by Faure for identification and thus are virtually cotypes, having been bred from *Anarsia lineatella* at the Station Entomologique du Sud-Est (St. Genis-Laval, Lyon).

Dr. Ferrière tells me that he replied to the effect that these specimens were "close to *xanthostigmus*." This is, of course, in the main correct; but *anarsiae* is certainly a distinct species, despite Faure's remarks with regard to "un systématicien pointilleux." It is clear to me that this latter author, as others, has entirely failed to appreciate the extreme importance of the carination of the propodeon. Neither do I agree with Faure's remarks relative to the length of the ovipositor sheaths; I consider the relative length of these to be invariable within reasonable limits.

In view of the importance of the host record and of the necessity of satisfactorily establishing the identity of as many as possible of the numerous species of *Apanteles* described from the Palaearctic region, I give a short redescription :—

♀. Black; front femora except at base, middle femora apically, the anterior tibiae and tarsi, and to some extent the hind tibiae at extreme base, red testaceous;

palpi and tibial spurs pale ; wings hyaline, the costal veins and a narrow border round the stigma more or less testaceous, the metacarp darker ; stigma discally hyaline or but faintly pigmented.

♂. Agrees with the ♀ save that the front femora are more extensively darkened, with the middle femora and hind tibiae entirely black, and the middle tibiae black in the apical three-fourths.

♀♂. *Head* : face minutely (degree 1) and evenly punctate ; clypeus not differentiated. *Thorax* : mesonotum with very close punctation (degree 3), almost minutely rugose anteriorly ; disc of scutellum with the punctation sparser and weaker than on the mesonotum, very flat and in the same plane as the posterior half of the mesonotum ; propodeon with some punctation ; the areola well marked and definitely closed basally, its carinae, and the costulae, strong, as is also a median longitudinal carina that occurs in the basal third of the propodeon and which extends from the obtusely closed base of the areola to the base of the propodeon. *Legs* : hind coxae on outer faces evenly punctate (degree 1–2), basally above rather more strongly and more closely punctate, or even strongly punctate (degree 3–4) ; the longer hind tibial spur half the length of the basal joint of the hind tarsus, the other spur a little shorter. *Abdomen* : 1st tergite of ♀ rugose but not coarsely so, somewhat arched, with a median raised area, basally to which the tergite is smoother and slightly excavate, medianly at apex with a small, shining, more or less smooth, raised area, the tergite with apical breadth rather less than median length and greater than basal breadth (26 : 30 : 20), the apical angles not rounded, the apical margin to some extent emarginate, in the ♂ with the apical third smoother so that the smooth median area at apex is hardly apparent, the sides of the tergite virtually parallel (possibly just slightly converging at extreme apex), and with length about twice median breadth (24 : 12) ; 2nd tergite in ♀ minutely rugose, with its apical margin angled medianly, with its median length less than one-fourth its extreme breadth and three-fifths median length of 3rd tergite (6 : 26 : 10), in the ♂ indefinitely sculptured, with the apical margin evenly rounded so that the lateral margins are equal in length to the median length, this latter hardly less than half extreme breadth of tergite (apical breadth) and three-fifths median length of 3rd (6 : 16 : 10) ; ovipositor sheaths longer than the hind tarsus, longer than the abdomen, both ovipositor and sheaths strongly decurved towards apex.

Apanteles anarsiae runs in my revised key to *earterus*, Wilkn., which latter, however, has no median longitudinal carina in the basal third of its propodeon, has the areola open basally, and its 1st and 2nd tergites not describable as rugose.

One of the males forwarded to us by G. J. Haeussler is immature.

Apanteles talidicida, sp. n.

♀♂. Remarkably like *Apanteles disputabilis*, Ashmead, but differing therefrom in at least the following characters :—

The malar space entirely testaceous, this testaceous area extending from base of mandibles to the eye, and from the facial depressions to as far behind the eye ; posterior polished area on lateral faces of scutellum small, semi-circular ; areola definitely U-shaped ; stigma uniformly opaque dark brown, as are the majority of the wing-veins ; wings slightly, but definitely, infumated at apex ; the nervellus strongly angled at or somewhat above middle, the lower portion strongly curved back towards base of wing.

British Guiana : Berbice, 3 ♀♀ (one the *type*), 1 ♂, 2–3.iii.1924, 2 ♀♀, 1 ♂, 26.ii.1924 (*H. E. Box*).

Type deposited in the British Museum.

Host. Both series are stated by Mr. Box to have been bred from larvae of the Hesperiid butterfly, *Talides sergestus*, Cram., feeding on the leaves of a species of wild *Heliconia* (wild plantain) in second growth jungle.

Cocoons white, in a white, more or less conglomerate mass.

Apanteles talidicida runs in Muesebeck's key (1920) to *insularis*, Mues.; it is clearly distinct from this species, however, if only on the length of the ovipositor sheaths and on the nature of the mesonotal punctation. On the other hand, if couplet 9 of Muesebeck's key were to be ignored, this new species would run to *disputabilis*, Ashm., to which latter *talidicida*, on account of its apically darkened hind femora, testaceous tegulae, basally closed areola, and minutely punctate mesonotum, runs in my key also.

I have used the following characters in my key, *disputabilis* being represented in the British Museum by males only :—

Stigma uniformly opaque dark brown; nervellus strongly angled at or above middle the lower portion strongly curved back towards base of wing; posterior polished area on lateral faces of scutellum small, semicircular (British Guiana) *talidicida*, Wilkn.

Stigma discally hyaline; nervellus but weakly angled and that definitely below middle the lower portion only very weakly curved backwards; posterior polished area on lateral faces of scutellum large, triangular (West Indies; U.S.A.)... ... ... *disputabilis*, Ashm.

Apanteles aethiopicus, sp. n.

♀. Black; the front femora (except in basal fourth), the middle femora (except at extreme apex), the anterior tibiae and tarsi (except the middle tarsi, which are very slightly darkened in apical third), and about basal half of hind tibiae, red testaceous; apical half of hind tibiae, hind tarsi, darkened to strongly darkened; palpi and tibial spurs pale; costal veins more or less testaceous; stigma, which is apparently without basal cloud, metacarp, radial and transverse cubital veins, and pigmented portion of the 2nd cubital vein, brown, remaining wing-veins colourless.

♂. Agrees with the above description of the colour of the female except as follows: Hind tibiae red testaceous in basal two-fifths, otherwise strongly darkened; costal veins testaceous; stigma hyaline, its upper margin together with the metacarp dark brown, its lower margins only faintly pigmented; wing-veins otherwise colourless.

♀♂. *Head*: face with minute punctation; vertex and occiput with minute, indefinite, closely placed punctation; clypeus hardly differentiated, the suture obsolete; facial depressions nearer to apex of clypeus than to eyes; posterior ocelli nearer to each other than to the eyes. *Thorax*: mesonotum in the median two-thirds of the posterior half with separated, but not widely so, strong (degree 3–4) punctation, across the extreme posterior margin almost smooth, in the lateral sixths and in the anterior half with minute (degree 2) but separated and distinct punctures; disc of scutellum smooth and shining save for minute but distinct punctation along the side ; ropodeon anteriorly to the costulae on each side of the areola with coarse punctation that gives a rugose effect, otherwise highly shining and more or less smooth, with the areola almost as broad at apex as medianly and well marked, the well-marked costulae horizontal; in the ♂ the carination of the costulae and areola, and the basal punctation, commonly, but very far from always, considerably weaker than in the ♀, so that sometimes both the costulae are obsolete, and the basal part of the propodeon is impunctate and shining. *Wings*: the 1st abscissa of the radial distinctly angled with, and 1·3 times as long as, the transverse cubital, the relative lengths of these veins, however, decidedly variable so that often they are of equal

length and often also with their point of junction rounded and hard to determine; stigma with its breadth equal to the length of the 1st abscissa of the radial, and with its length equal to that of the metacarp. *Legs*: hind coxae above with some minute (degree 1), very sparsely placed punctures, with the greater part of the upper half or two-thirds of the outer faces impunctate and smooth; hind tibial spurs subequal, the longer spur half the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite with basal breadth about two-thirds the median length (14 : 22), parallel-sided in the basal half, then slightly widened so that its greatest breadth, which is slightly before apex, is distinctly broader than base (17 : 14), narrowing again at apex and the apical angles rounded (particularly in the ♀), with the integument entirely smooth in the basal half, and in the apical half medianly with some indefinite punctures and sculpture giving a roughened effect; 2nd tergite entirely smooth (save for the usual minute punctation), even the lateral sulci more or less obsolete, in outline more or less rectangular (the lateral sulci, particularly in the ♀, only slightly diverging) with median length in ♀ about one-third apical breadth and about half the apical breadth of 1st tergite, in ♂ with the apical breadth only 2·5 times median length, which latter is not greatly less than the apical breadth of the 1st tergite (8 : 12); 2nd suture very fine; succeeding tergites as smooth as the 2nd; hypopygium moderately large, acute; ovipositor sheaths short, 1·3 times as long as the basal joint of the hind tarsus.

Length: ♀, 2·5 mm.; ♂, 2·0 mm.

UGANDA: Kampala, 76 ♀♀ (one the *type*), 55 ♂♂, 2.vii.1929 (per *G. L. R. Hancock*). ITALIAN SOMALILAND: 11 ♀♀, 4 ♂♂, 1926 (*Prof. Paoli*). SIERRA LEONE: Njala, 57 ♀♀, 3 ♂♂, 8.ii.1929 (*E. Hargreaves*).

Type deposited in the British Museum.

Host. The series from Uganda is labelled "*ex* ? Lasiocampid with Tachinids," while the series from Njala is equally without host record, only bearing a number, 372; of the material from the Italian Somaliland some of the specimens are labelled as parasites of the Arctiid moth, *Utetheisa pulchella*, L., and others of the Pyralid, *Antigastra catalaunalis*, Dup.

Cocoons. Only those of the specimens from the Italian Somaliland are known; these are white and indiscriminately heaped together.

Apanteles aethiopicus is a distinctive species on account of its smooth 2nd tergite and hyaline male stigma. A widely distributed species, it is to be regretted that the material from Uganda and Sierra Leone is without host record.

Of the specimens before me I consider that only those from Uganda are fully mature. It is particularly noticeable that the series from Sierra Leone is immature, since here in almost every instance has the abdomen collapsed. Further, the wings of both the Somaliland and Sierra Leone material bear evidence of immaturity: the stigma is rarely completely pigmented, and the wing-veins, particularly the radial and transverse cubital veins, have not that strength and rigidity of outline associated with fully mature material. The question of the immaturity of these two series is of importance since certain minute differences are commonly noticeable between them and that from Uganda. The former commonly have the punctation of the mesonotum shallower and smaller, while the 1st tergite of the ♀♀ very often tends to be more parallel-sided than in the series from which the type has been selected, thus making the ♀ 1st tergite more like that of the ♂.

Microgaster vacillatrix, Wilkinson 1930.

Information has been received from Mr. Hancock with regard to the host of this species: this, he writes, has now been determined as the Pyralid, *Filodes costiventralis*, Guen.

PHYTALUS (COL., MELOL.) IN SUGAR-CANE IN MAURITIUS.

By D. D'EMMEREZ DE CHARMOY,
Director of Agriculture, Mauritius.

Like Mauritius, many other cane-growing countries in the world are suffering severely from the ravages of Lamellicorn beetle grubs. In some of these countries, such as Australia, India, South America and the West Indian Islands, these insects are indigenous, whilst in others, such as Hawaii and Mauritius, some of them have been accidentally introduced.

Through intensive cultivation of sugar-cane, which in some places is the staple industry, these so-called white grubs have found an abundance of food and an adequate environment, so that they have become, even in their country of origin, a major pest of sugar-cane; whilst in places where they have been introduced, the damage done, in some cases, is a serious menace to the sugar industry.

Heavy annual losses are being sustained in the Philippines, Queensland and Porto Rico; at present the damage in Porto Rico is estimated to be 3 million dollars yearly.

In order to cope with such a state of affairs, all possible effort is nowadays being made in most of these countries to try to control the pests by rational and scientific methods. Though many important points have been solved by research workers engaged thereon, there still remain many unknown factors upon which enlightenment is required.

The Melolonthid beetle, *Phytalus smithi*, Arrow, was first recorded as a pest in Mauritius in the year 1911, the principal focus of infestation being at Pamplemousses. The insect was apparently imported from Barbados.

Judging from the damage, which extended over about 3,000 acres, of which 300 acres were highly infested, it is probably correct to state that this insect must have been present in Pamplemousses for at least 6 years before it was recognised.

Though prompt and energetic measures were taken for its control, the possibility of multiplication of foci was always regarded as ultimately inevitable, since the complete restriction of the pest to the original infested areas would have entailed an impossible embargo on all forms of traffic from those areas during the three or four months of the year in which the adults are about.

From 1911 to 1930, five important foci were discovered, at intervals of 9, 14 and 16 years since the original infestation at Pamplemousses. It is apparent that in all these centres the pest, which has been conveyed by means of cane transports and motor cars travelling at night, must have existed for many years previous to its discovery, and in some cases was not reported to the Department of Agriculture by the planters concerned for fear that measures might be taken by the Government which might in their opinion be prejudicial to their interests. *Phytalus* is now disseminated over a total area of 46,000 acres, distributed as follows:—

Pamplemousses and Rivière du Rempart	28,000
Savanne and Grand Port	5,000
Moka and Plaines Wilhems	9,000
Flacq	4,000
	46,000

Though the pest exists in 46,000 out of 170,000 acres planted in cane, the area of appreciable damage is restricted to about 3,200 acres, approximately divided as follows :—

Rivière du Rempart	1,000	acres
Savanne and Grand Port	700	,,
Moka and Plaines Wilhems	1,000	,,
Flacq	500	,,
	3,200	,,

This position has been brought about by the control measures adopted. It is clear that the expenditure incurred has resulted in a saving to the Sugar Industry when compared with the heavy loss which would have been sustained by planters had not stringent and energetic measures been taken since the beginning of the campaign.

On comparing the relation of the heavily infested area to the total area infested at the outbreak of the pest at Pamplemousses in 1911, with the present situation in 1929–30, it is interesting to note that the percentage of heavy infestation is lower by 3 per cent.

Moreover, the degree of infestation, when expressed as the number of insects destroyed per acre infested in the various centres, is practically the same or less at the present time when compared with the original infestation, as shown in the following table :—

PAMPLEMOUSSES AND RIVIÈRE DU REMPART.

Year 1911, about 3,000 acres originally infested ; mean number of insects collected per acre = 8,800.

,, 1929–30, about 28,000 acres infested ; mean number of insects destroyed per acre = 4,444.

SAVANNE.

Year 1920–21, about 300 acres originally infested ; mean number of insects destroyed per acre = 4,333.

,, 1929–30, about 5,000 acres infested ; mean number of insects destroyed per acre = 6,186.

MOKA AND PLAINES WILHEMS.

Year 1925–26, about 1,000 acres originally infested ; mean number of insects destroyed per acre = 22,000.

,, 1929–30, about 9,000 acres infested ; mean number of insects destroyed per acre = 9,200.

FLACQ.

Year 1927–28, about 1,500 acres originally infested ; mean number of insects destroyed per acre = 8,600.

,, 1929–30, about 4,000 acres infested ; mean number of insects destroyed per acre = 4,497.

Such a state of affairs may be expected to continue for at least 20 or 30 years or more, judging from the rate of spread, which is exceptionally slow when compared with the spread of similar insects in other countries ; for the original infestation has extended to only 46,000 acres in 25 years, as shown above. During that period the

number of insects captured each year is therefore bound to increase, and a time will eventually come when the whole island will be infested.

The spread of unchecked *Phytalus*, when considered alone, and the spread of *Tiphia*, also considered alone, might be represented by the two curves A and B (fig. 1). *Phytalus* had a start of at least 12 years on *Tiphia*, so that the two curves do not develop synchronously. The hypothetical curve that would represent the development of *Phytalus* when parasitised by *Tiphia* is shown at E. It would thus appear that *Phytalus* would develop normally at first, then as the influence of *Tiphia* begins to be felt, the curve of development would bend inwards at D and a new curve of development would follow, reaching its maximum at E. Finally, the curve would probably fall rapidly, reaching ultimately a point when it would keep at a constant value : meaning that the pest is completely controlled by *Tiphia*.

At present, the damage done to canes by *Phytalus* is confined to the heavily infested area, 3,200 acres. The reduction in yield might be reckoned at an average of 4 tons of cane per acre at an average of Rs.10 a ton in badly infested fields ; but it is not uncommon to see infested fields still giving an adequate yield, mainly owing to good cultural methods combined with a systematic control of the pest.

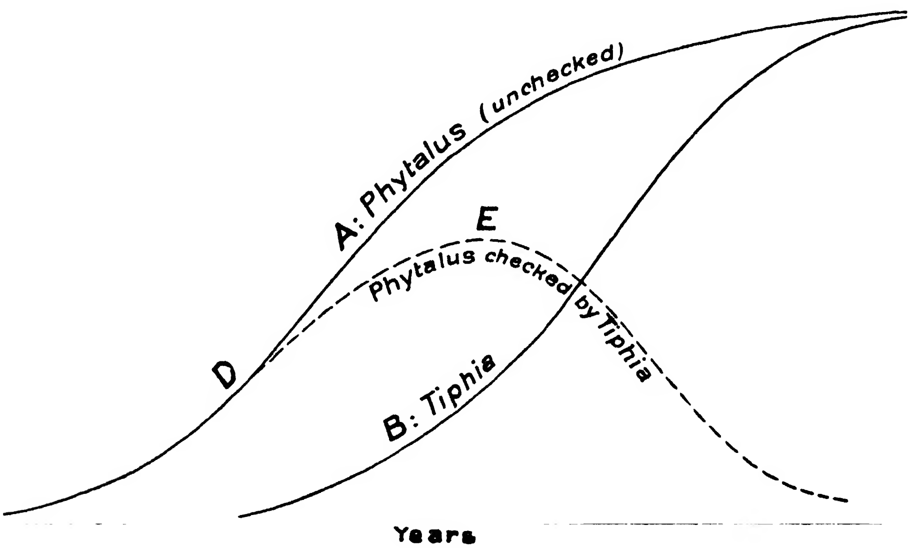

Fig. 1.

It is noteworthy that the total number of insects destroyed since 1911 amount to 1,704,000,000. The cost per 100 of these insects has been Rs.0.05½. The expenditure on the campaign is sustained partly by the planters' fund (duty of Rs.0.02 per 100 kilos. of sugar exported each year) and partly by the Government Development Fund. Considering that this pest has been in the Colony for 25 years and that three-fourths of the area planted in cane has been kept free from it, while of the remaining fourth one-nineteenth only is heavily infested, there can be little doubt that the expenditure has been entirely justified ; for had not any control been effected, the pest would have cost millions of rupees instead of Rs.905,130—the sum actually expended on the whole campaign. In Porto Rico a similar pest is causing an annual loss of three million dollars as reported by Mr. H. E. Box.[6]

The measures of control that continue to be in force are (*a*) hand collection, (*b*) digging of larvae, (*c*) application, when possible, of various insecticides such as Cyanogas, Cianidra, paradichlorobenzene, etc., (*d*) systematic liberation of parasites.

Hand collection is sometimes deprecated as an unscientific method, but the following figures will prove its usefulness: at a certain period, in December as a rule, a night's collection amounts to 18,000,000 insects and entails an expenditure of only Rs.1,800.

During the past five years, digging of larvae has been done on a large scale, with the result that 205,000,000 have been destroyed at a cost of about 3 cents of a rupee per hundred. This method of destruction serves a twofold purpose: (1) destroying the larvae and diminishing reinfestation in the next season; (2) giving a better tilth to the soil and thus improving plant growth.

Every effert has also been made with a view to finding an efficient insecticide, moderate in cost and of easy application. Chemicals such as paradichlor, Cyanogas and Cianidra, though they are powerful insecticides, cannot be employed economically in practice owing to their high cost and the labour which their application entails. The cost of treatment of one acre of land with Cyanogas at a dose of 7 grams to a stool amounts to about Rs.96 without reckoning labour.[1] There remains the biological control by means of parasites which have been introduced to check this pest.

As regards *Tiphia parallela*, this insect was successfully introduced into Mauritius from Barbados in the year 1916; an account of this importation has been given in the Bulletin of Entomological Research.[2] This parasite was noticed in the year 1917–18 in fields where it was liberated and has since acclimatised itself well over the whole infested region through subsequent systematic distribution. *Phytalus* had certainly been established in Mauritius some twelve to fifteen years before the *Tiphia* was introduced and the start which it thus had over its parasite gave it a very great advantage. It is now only thirteen years since *Tiphia parallela* began its beneficial work in the Island, and years must elapse before it can reach a state which will bring about equilibrium.

At present, the degree of parasitism of *Tiphia*, which is as high as 30 per cent. with an average of 20 per cent. and a minimum of 7 per cent., is about the same as shown by Nowell in Barbados.[3] It appears therefore that *Tiphia* has as completely established itself in Mauritius as in the country from which it was imported. It is at present not uncommon to find thousands of these beneficial insects in heavily infested cane fields.

In order to push on the work of *Tiphia*, this insect is liberated in the slightly infested zone about 1 to 1½ miles from the heavily infested centres, with a view to counteracting the infestation as the pest spreads.

There may, however, be some unknown factors that assist in keeping the equilibrium, as it has been noticed that in places where the pest had reached its climax it has thereafter practically disappeared in periods varying from 2 to 4 years, whilst the infestation is still going ahead. In such places it is difficult to find even a few insects. This has been the case in some localities of Pamplemousses, Moka and Savanne. This question is no doubt an important one and has been for the past few years under careful consideration by the Entomological Division of the Agricultural Department, and experiments are now in hand to elucidate it.

There may, however, be occurrences from time to time of sporadic outbreaks of high intensity at points which have been previously cleared of *Phytalus* and consequently abandoned by *Tiphia* until the latter re-establishes itself therein. Instances of this nature have in fact been already noticed in the Pamplemousses district, and in Barbados, where this beetle is still considered to be one of the major pests of the sugar-cane.

With regard to other parasites, another Scoliid wasp, *Elis thoracica*, was imported from Madagascar in the year 1917.[4] This insect has established itself readily on

Phytalus and is found at present in most of the infested cane fields of the Island. Its mode of life in no way interferes with the work of *Tiphia* as its eggs are attached to the larvae of *Phytalus* under the abdomen, whilst the eggs of *Tiphia* are stuck on the thorax. Owing to its high power of adaptation, great hope is entertained with regard to its usefulness.

Examples are common in Mauritius of various pests being kept under control by introduced or indigenous natural enemies, as for instance the white grubs of *Rhizotrogus gravidus*, *Rhizotrogus pallens* and *Oryctes tarandus*. The first two are indigenous species living on sugar-cane but are not considered as pests, being kept under control by an indigenous Scoliid wasp, *Elis rufa*. The same applies to *Oryctes tarandus*, which is nowadays kept under control by *Scolia oryctophaga*, a wasp introduced into Mauritius from Madagascar in 1917.[4] As these pests behave similarly to *Phytalus*, there is no reason why *Elis thoracica* and *Tiphia parallela* should not at some future date bring about the same state of equilibrium.

At the present juncture, it appears that the artificial mode of destruction by hand collection, whatever may be said about it, combined with the biological mode of control, is plainly justified. The following extract from an article on biological control in "Parasitology," by Dr. W. R. Thompson,[5] can be aptly quoted here :—

"The introduction of parasites will, of course, give no relief until their numbers have increased to the point where they exterminate a sufficient fraction of the available population to produce control, and during the interval artificial methods must necessarily be employed."

The introduction of new parasites would probably serve no useful purpose, and in this respect the following quotation from the same author is most interesting :—

"It may be taken as an axiom in parasitic work that two species having the same habits in attacking the host in exactly the same way accomplish no more than one, being in fact for practical purposes exactly like different individuals of the same species."

Nevertheless, much information has been sought from other countries where similar pests exist, namely, Porto Rico, Queensland, etc., and there appears, according to Mr. H. E. Box, to be a Scoliid wasp, *Elis caracasana*, found in Venezuela and British Guiana, "the introduction of which might be worth trying in Mauritius as well as in Barbados."

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(1) Report on the Operations for the Control of *Phytalus smithi* during Season 1927–28 & 1926–27.
(2) Bulletin of Entomological Research, viii, 1917, pp. 93–102.
(3) West Indian Bulletin, xv, 1916, p. 151.
(4) Bulletin of Entomological Research, xiii, 1923, pp. 245–254.
(5) Parasitology, xx, 1928, pp. 93, 109.
(6) Porto Rican Cane Grubs and their Natural Enemies.—J. Dept. Agric. Porto Rico, ix, 1925, no. 4, pp. 291–356.

LARVAE OF ETHIOPIAN MOSQUITOS.*

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During work on mosquitos in Uganda a certain number of hitherto undescribed larvae have been found; advantage has also been taken of the opportunity to re-describe from fresh material some species of which the published descriptions are (in the light of our increased knowledge of mosquito larvae) found to be inadequate.

Unless otherwise stated all larvae are from the neighbourhood of Kampala. All descriptions are of fourth-stage larvae, and in every case identification of larvae has been made by comparison with the cast skins of isolated specimens from which adults have been bred. The nomenclature used for the head-setae is that proposed by Edwards & Given; measurements of the head are always maxima. As the setae of the thorax and abdomen do not appear usually to be of much value for purposes of specific identification descriptions of them have in most cases been omitted.

For determination of adults and other assistance the writer is greatly indebted to Mr. F. W. Edwards, of the British Museum.

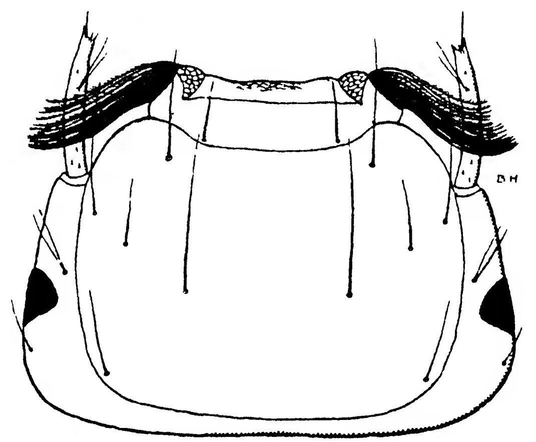

Fig. 1. *Mucidus africanus*, Theo., head.

Mucidus africanus, Theo. (figs. 1, 2).

Described from one skin and one whole larva. Length about 10 mm.; colour yellowish white, mouth-brushes and valves of siphon dark brown.

Head quadrangular in shape, somewhat broader than long (1·2 : 1). Mouth-brushes set very wide apart, the hairs modified into strong, highly chitinised spines, each edged apically with a row of small teeth as in *Lutzia tigripes*, Grp. (Wesché, pl. iii, fig. 15). Antenna very short (1/3 as long as width of head) and slender, not infuscate, with very few minute spicules; antennal tuft of two short simple branches at 5/6; terminal and subterminal setae very small. Clypeal spines placed very far back, as in *Pardomyia aurantia* (Edwards & Given, p. 341) but long and slender, almost reaching anterior margin of head. Clypeal hairs all single and not plumose.

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Mentum* with about seven small teeth on each side of the median longer tooth. I am unable to find any differences between the mandible of this species and that of *Pardomyia* as figured by Edwards & Given. *Abdomen*: comb consisting of about 60 approximately equal teeth arranged roughly in a semicircle; each tooth with a broad apical fringe. Siphon moderately long (index 3–4 : 1 in preserved specimens, probably somewhat more in fresh ones); a single subventral tuft of six or seven simple branches at about a half; pecten of about twenty teeth extending to about a third, teeth with one or two strong basal denticles, last three teeth more widely spaced than the remainder and simple. Anal segment moderately chitinised, saddle extending over the greater part of the segment; posterior margin of the saddle with a small number of rather large coarse spicules dorsally; both pairs of dorsal setae single, approximately equal; lateral hair single, simple, about as long as anal segment. Ventral brush very strongly developed, composed of about 16 pairs of

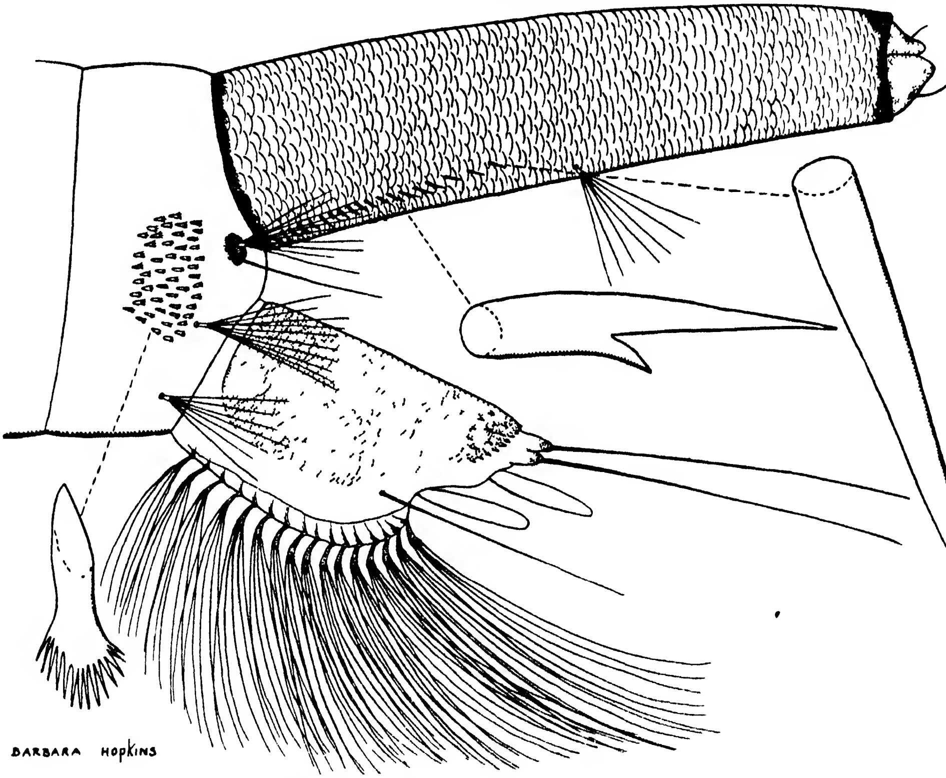

Fig. 2. *Mucidus africanus*, terminal segments of abdomen.

tufts, but individual tufts short and with simple branches. Gills very short (about half length of anal segment), dorsal and ventral pairs approximately equal.

This larva may readily be distinguished from that of *M. scatophagoides*, Theo., which has been described from African material by Bedford (1918, p. 739) by the larger number of comb-scales (about 60 instead of 30–40) and the fact that the tuft on the siphon, placed in this species at almost exactly a half, is in *M. scatophagoides* apparently always well before a half and sometimes nearly at a third. The shape

* The mental plate differs considerably in shape in the two specimens examined, but similar differences exist in a short series of larval skins of *Mucidus scatophagoides* from West Africa kindly lent me for comparison by the London School of Hygiene and Tropical Medicine.

of the mentum, the siphonal index, and the number of spines in the pecten seem to be very variable in both species.

Edwards (1924, p. 367) states of the genus *Mucidus* that in spite of the characteristic appearance of the adult it "is really quite closely related to the subgenus

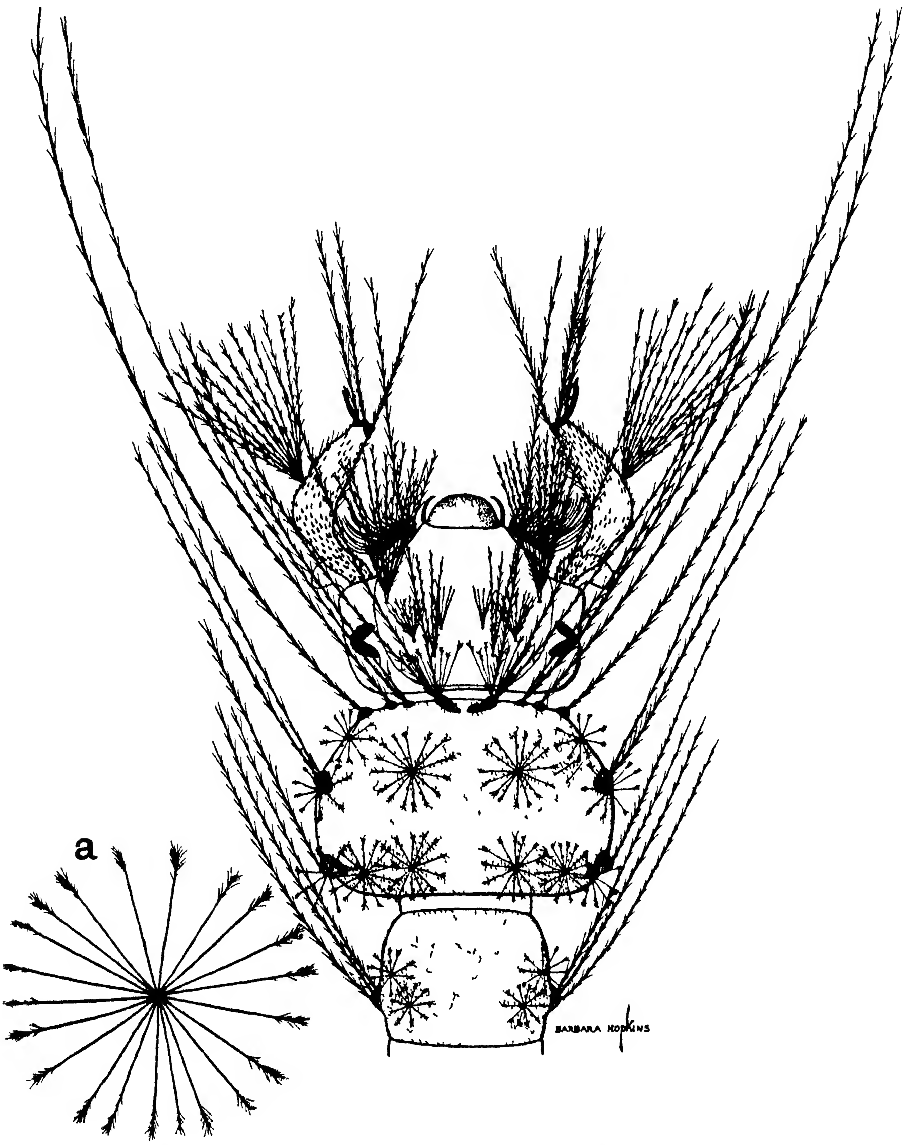

Fig 3 *Aëdomyia furfurea*, End , head, thorax, and first abdominal segment , *a*, stellate seta of abdomen.

Ochlerotatus of *Aëdes*." This statement is strongly confirmed by the structure of the larva, which, with the exception of the various modifications in connection with its predatory habits, closely resembles that of an *Ochlerotatus*.

Aëdomyia furfurea, End. (figs. 3, 4).

Described from four skins and four whole larvae. Length about 9 mm.; colour green or olive-green.

Head broadly triangular, length and breadth approximately equal. Antenna very large, flattened, similar to that of *A. africana*, N.-L. (Edwards, 1912, p. 378, fig. 4, as *A. catasticta*), strongly curved, shaft covered with short hairs; tuft at 3/5 composed of about twelve long plumose branches; subterminal bristles long and plumose, slightly longer than the shaft; terminal bristles minute. Clypeal spines short, stout and curved; clypeus produced between them as a semicircular projection. Palps similar to those of *A. africana*. On the ventral side of the head there arises a very peculiar paired bladder-like structure between the bases of the maxilla and palp; this structure is apparently retractile, as in some specimens it appears expanded on one side and collapsed on the other. It is perhaps homologous with the " membranous finger-shaped process arising between maxilla and palpus . . ." mentioned by Howard, Dyar & Knab in their description of the larva of *Aëdomyia squamipennis* (Mosquitos of North and Central America, iv, p. 897). Clypeal setae large, A, B and C plumose, with about 12, 9 and 3 branches respectively; *d* with about 5 simple branches; *e* single, simple. Mentum very small, almost square, with two teeth on each side of the central tooth. *Thorax*: the pair of chitinous plates near the middle of the anterior margin of the prothorax large, each bearing three very long plumose setae and a tuft of very numerous short, slender branches with a peculiar form of plumosity, which in the writer's experience is unique: the shaft of each branch is but slightly pilose, whereas near the tip the secondary branches form a definite tuft strongly reminiscent of the tuft of hair on the tail of an elephant; the hairs external to these chitinous plates are immensely long, reaching to as far again as the tips of the branches of the antennal tuft, their plumosity is normal and they have two, one, one and one branches respectively. Lateral tufts of meso- and metathorax composed of similar immensely long plumose hairs which arise from large chitinous bosses, of which that of the metathorax is very pronounced. Meso- and metathorax each with two pairs of large stellate dorsal tufts; a similar but smaller stellate seta arises at the base of each of the lateral tufts of these two segments. These stellate setae, together with those of the abdomen, show the same peculiar plumosity as those on the prothorax but in a more marked degree, since the shaft is entirely bare, accentuating the tufted appearance of the tip. *Abdomen*: lateral tufts similar to but smaller than those on the thorax present on segments 1–7, but especially well developed on segments 1 and 2. Numerous stellate tufts similar to those of the meso- and metathorax are also present. Comb a row of about 15 long simple spines set on the edge of a large chitinous plate. Siphon short and weakly chitinised, index 3 : 1 There is no trace of a pecten, nor of the definite rows of soft hairs present in *A. africana*, but the whole surface of the siphon is covered with short hairs which are longer and more numerous near the tip on the ventral side. A subventral tuft of about six plumose branches (which are more than 1·5 times as long as the siphon) is situated at 0·75. A rather stout, short, simple subdorsal seta is present, as in *A. africana*; the pair of strong curved spines at the tip of the siphon found in *A. africana* is present in this species also. Anal segment weakly chitinised, with very strong pilosity on the dorsal side as in *A. africana*. Upper and lower dorsal setae single, very long, with very coarse and long unilateral plumosity; lateral seta as long as anal segment, with three slightly plumose branches; ventral fin composed of six pairs of single coarsely plumose setae. Gills very short (slightly more than half the length of the anal segment), bluntly pointed.

The whole surface of thorax and abdomen has a dense covering of minute setae.

Immediately separated from *A. africana* by the fact that the comb is set on the edge of a large chitinous plate and by the unique character of the stellate setae.

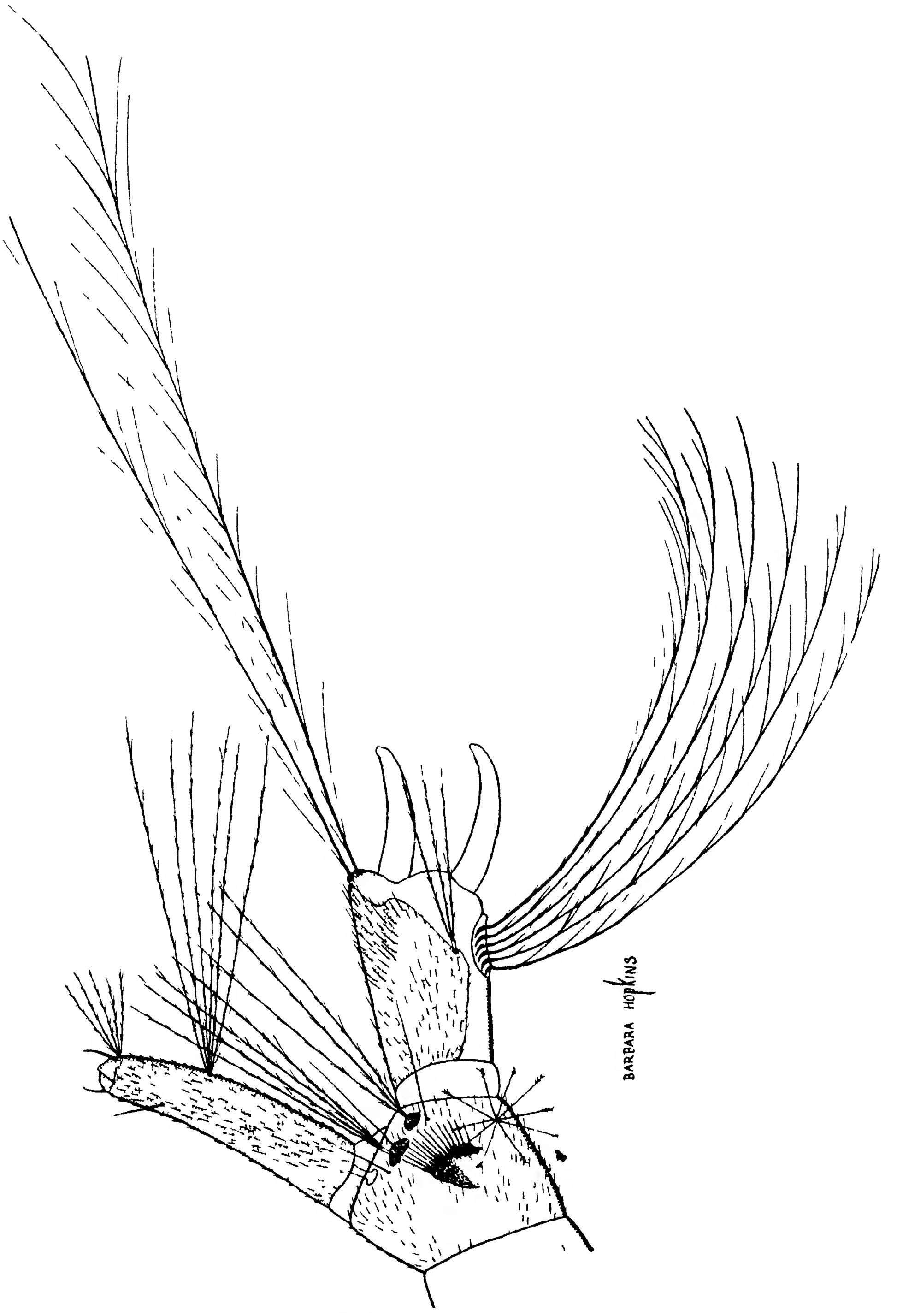

Fig. 4. *Aedomyia furfurea*, terminal segments of abdomen.

Mimomyia mimomyiaformis, Newst. (figs. 5, 6).

The larva of this species has been described by Wesché (p. 47, as *Megaculex pincerna*). Larvae from Kampala differ from his description and from the particulars given in Edwards' key (1912, p. 383) and are described below.

Described from five skins. Colour whitish, head and siphon very dark brown.

Head: antenna as in *M. hispida*, Theo. (Macfie & Ingram, 1917, p. 15) but discrepancy in length of the two apical setae markedly greater; the tuft consists of about a dozen branches and is situated at a little beyond a half. Clypeal spines

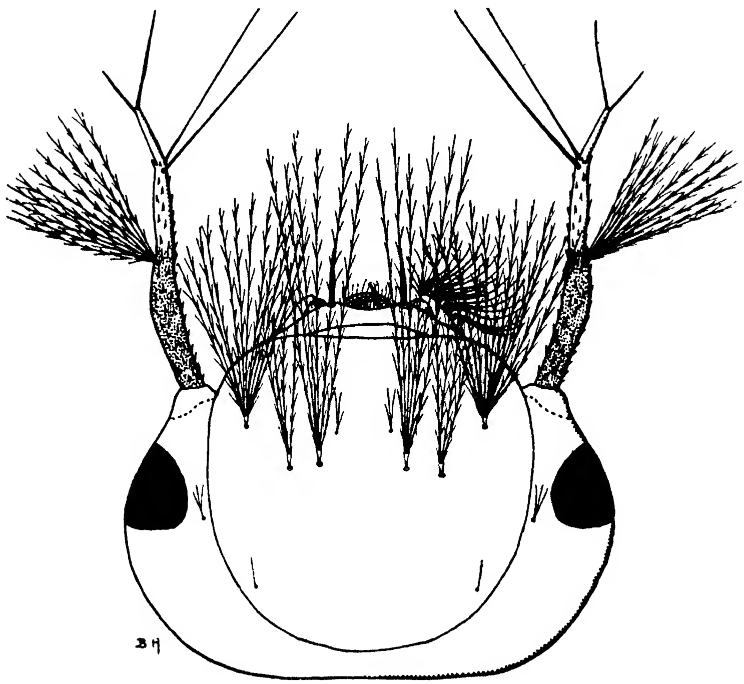

Fig. 5. *Mimomyia mimomyiaformis*, Newst., head.

stout, curved and black. Clypeal setae A, B and C strongly plumose, not so long as in *M. hispida* (B and C somewhat less than length of head), A with about 12 branches, B and C with 3 and 5 or 6 respectively; *d* rather small, three-branched; *e* small, simple. *Abdomen*: comb of about 12–14 spines in a single row,* individual spines like those of *M. hispida*; siphon rather long (index about 5 : 1), pecten of two or three small weak spines in the same position as that of *M. hispida*; tuft on siphon situated at a half, composed of about 5 subplumose branches. Anal segment well chitinised, upper part of distal margin of saddle with numerous small spines; lateral

* A short series of larval pelts and whole larvae of *M. mimomyiaformis*, collected at Sapele, Southern Nigeria, by my friend Dr. V. B. Wigglesworth, agree with the Kampala specimens as regards the number of comb-scales, but some of them have in addition two or three scales placed distal to the main row, as in *M. hispida*; they are not, however, as in the latter species, larger than those of the main row.

seta plumose, very long (more than twice length of anal segment); upper dorsal seta with about 6, lower dorsal seta with about 3 simple branches. Fin of about four pairs of setae each with 3 or 4 simple branches. Anal gills damaged in all the specimens, apparently similar to those of *M. hispida* but somewhat shorter.

In general appearance the larva closely resembles that of *M. hispida,* from which it may easily be distinguished by the shorter clypeal setae and the usually single row of comb-scales.

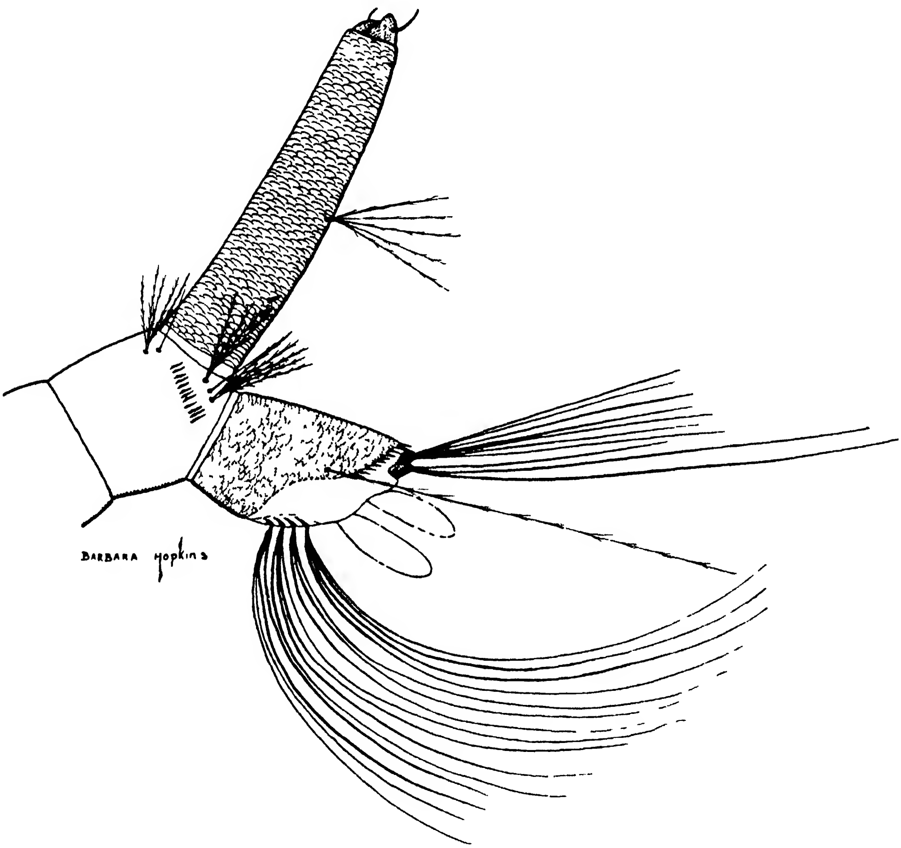

Fig. 6. *Mimomyia mimomyiaformis*, terminal segments of abdomen.

Culex quasigelidus, Theo.

Numerous specimens of this species have been bred from isolated larvae by the writer; these larvae agree very well with the descriptions and figures published by MacGregor (p. 175) and Kirkpatrick (p. 110).

Edwards' suggestion (1922, p. 102), repeated by Séguy (p. 30), that the larva figured and described by Ingram & Macfie as *C. univittatus* (Ingram & Macfie, 1919, p. 68) is an immature specimen of *quasigelidus* is certainly incorrect, though the

larva in question is not that of *univittatus* ; even immature specimens of the larva of *quasigelidus* show the characteristic curved shape of the siphon and long subventral tufts, besides other differences from the larva figured by Ingram & Macfie.

Culex hancocki, Edw. (figs. 7, 8).

Described from two skins and six whole larvae collected by Messrs. G. L. R. Hancock and W. W. Soundy from the bamboo forest on Mount Elgon at an elevation of about 9,000 ft. ; this material included the skins from which the type specimens were reared. Length about 7 mm. ; colour white, head, siphon and anal segment yellow.

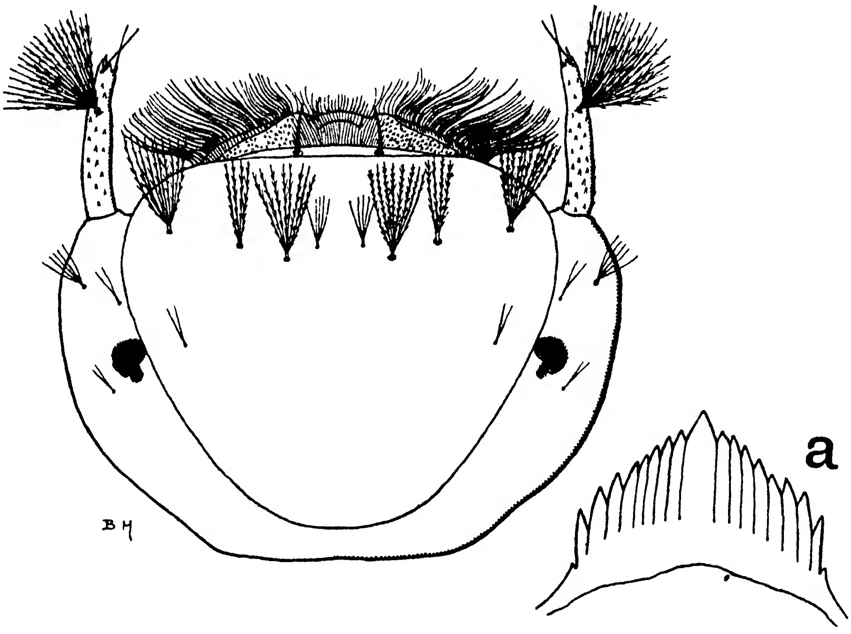

Fig. 7. *Culex hancocki*, Edw., head ; *a*, mental plate.

Head weakly chitinised, rounded, width slightly greater than length (1·2 : 1). Antenna infuscated only at extreme base, short, curved, slightly tapering ; shaft covered with small spicules ; tuft at 3/5, of about 20 very delicately plumose branches which appear simple at low magnification ; preapical and apical bristles short, preapical situated very close to the tip ; papilla minute. Clypeal spines rather long, slender and pointed. Clypeal setae A, B and C all short and composed of finely plumose hairs, with about 10, 4 and 8 branches respectively, the branches of C just reaching the anterior margin of the clypeus ; *d* with about 5 rather long simple branches ; *e* two-branched, slender. Mentum with a large median tooth, on either side of which are about ten teeth increasing in size towards the base. Eye very small, apparently obsolescent. *Abdomen* : comb of 10–12 small scales arranged in

an irregular patch, each scale with a long sharply pointed stout apical spine, the base of which is enveloped in a fine fringe. Siphon short (index 1·5 : 1), conical, weakly chitinised, acus present ; pecten extending rather beyond a third, of 4–6 simple spines ; the pecten is perhaps vestigial, the spines small and without branches, and their number often different on the two sides of the same larva ; the three pairs of subventral tufts are each composed of three or four branches about as long as the diameter of the siphon at the point of attachment, and with extremely delicate plumosity Anal segment weakly chitinised ; dorsal setae arising from small chitinous knobs, upper with about seven branches, lower single, longer and stouter than upper,

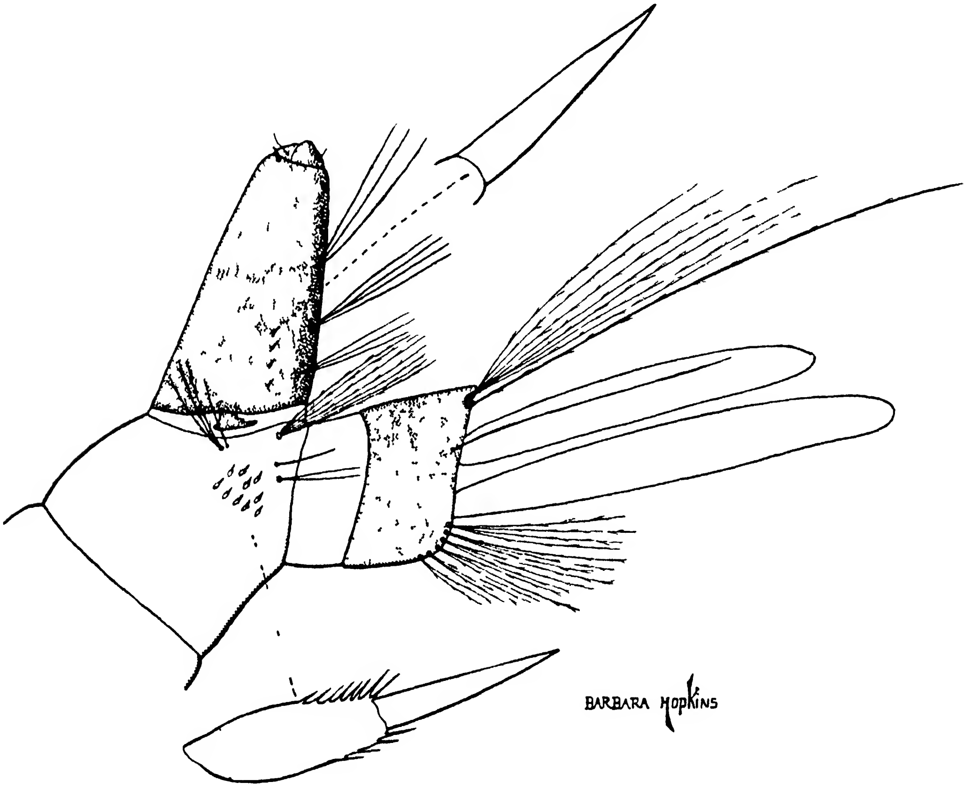

Fig 8 *Culex hancocki*, terminal segments of abdomen

both upper and lower very finely plumose , lateral seta single, long, simple, its origin close to the distal margin of the segment Ventral brush very feebly developed, composed of about six pairs of tufts, each with three or four short weak branches. Anal gills very large, sausage-shaped, dorsal pair slightly shorter than ventral, length of dorsal pair : length of anal segment as 4 · 1

This larva may be distinguished from any other described Ethiopian larva of the genus except *C. moucheti*, Evans, by the low siphonal index ; from that of *moucheti* it is readily separated by the presence of a brush on the anal segment.

, Edw. (figs. 9, 10).

A brief description of this larva has been given by Edwards (1914, p. 66). Further material has now come to hand and a fuller description can be drawn up ; no important differences from Edwards' description have been noted in the material examined. Described from four skins and eight whole larvae (Mount Elgon, about 7,000 ft., G. L. R. Hancock and W. W. Soundy). Colour yellow-brown, head and siphon dark brown ; length about 8 mm.

Head : antenna infuscate throughout, half as long as width of head, strongly spiculate, a large tuft of about 20 plumose branches at 3/5. Clypeal spines curved, slender. Clypeal setae A, B and C plumose, with about 7, 5 and 7 branches respec-

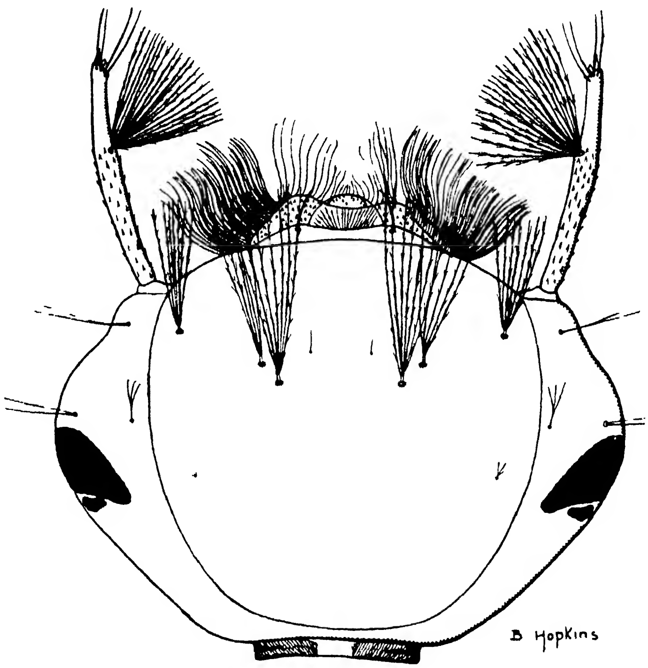

Fig. 9. *Culex andersoni*, Edw., head.

tively, bases of B and C very close together ; setae *d* and *e* minute, *d* simple and *e* with one or two branches. Mentum triangular, with about 12 teeth, increasing in size towards the base on each side of the median tooth. *Abdomen* : comb of about 60 approximately equal teeth with a rather long apical fringe ; siphon with well-marked acus, index 4–5 : 1 ; comb of 12–15 teeth, each with two or three very large basal denticles, last three teeth more widely spaced than remainder ; three pairs of alternating subventral tufts, each with 3–5 simple branches, lateral tuft of two or three branches at about 4/5. Anal segment with saddle well chitinised and covering almost entire segment. Dorsal setae simple, upper pair two-branched with dorsal branch half length of ventral; lower pair single ; lateral seta small (less than half length of saddle) two- or three-branched. Anal gills lanceolate, dorsal pair longer than ventral, about twice length of anal segment.

This larva very closely resembles that of *Culex pipiens*, L., but may be distinguished by the dark colour of the head and siphon and greater proportionate length of the anal gills. The last three teeth of the pecten are not markedly wider spaced in *pipiens*.

Culex guiarti, Blanch.

Much uncertainty appears to exist as to the larva of this species, three quite distinct larvae having been attributed to it. Numerous specimens of the species have been bred by the writer from isolated larvae which correspond well with that described and figured by Ingram & Macfie (1917, p. 150).

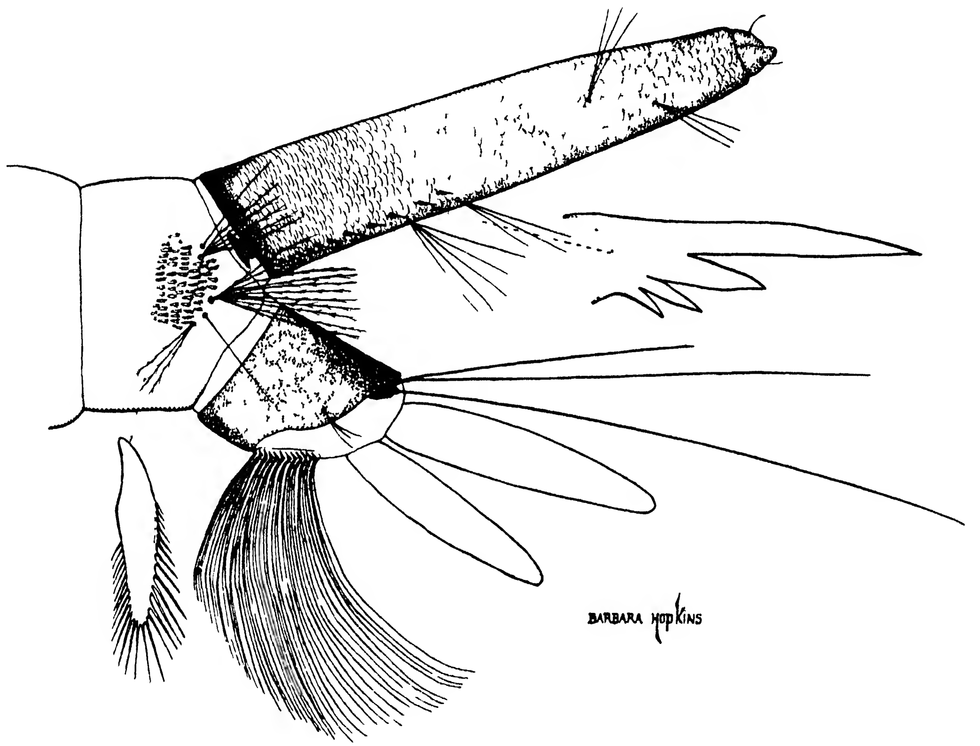

Fig 10. *Culex andersoni*, terminal segments of abdomen

Culex ingrami, Edw. var. (fig. 11).

Larvae of this species, as found in Kampala, differ markedly from those described and figured by Macfie & Ingram (1916, p. 11). The differences appear to be confined to the siphon, which is distinctly shorter (index 8–10 : 1) ; the pecten is composed of about 25 paired and slightly barbed spines becoming simple and alternate distally ; these spines presumably take the place of the unpaired spines present beyond the true pecten in the form described from the Gold Coast ; in the Kampala form the pecten appears to extend almost the entire length of the siphon and merges into the patch of about six closely appressed subventral and subapical spines present in both forms.

The differences are noted from six skins and three whole larvae. In addition to these, several dozen specimens have been encountered in the course of routine examinations; no specimens of the Gold Coast form have been met with.

The larva of *C. ingrami* in both its forms may be distinguished from that of any other known Ethiopian *Culex* by the presence of appressed spines on the ventral side

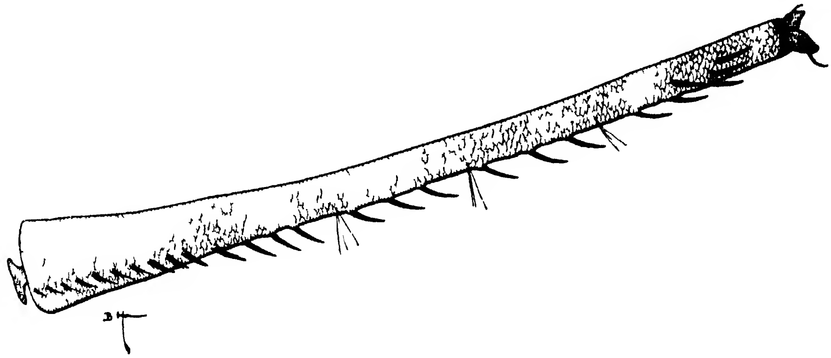

Fig 11 *Culex ingrami*, Edw., var., siphon

only of the tip of the siphon. *Culex vansomereni* (Ingram & De Meillon, p. 67 and fig. 25, as *C. draconis*) has similar spines near the apex of the siphon, but in this case they are dorsal as well as ventral.

Culex (Culiciomyia) nebulosus, Theo. (figs. 12, 13).

The larva of this very common species seems never to have been described, since neither of the larvae described by Wesché (as *Pectinopalpus fuscus*) belong to the

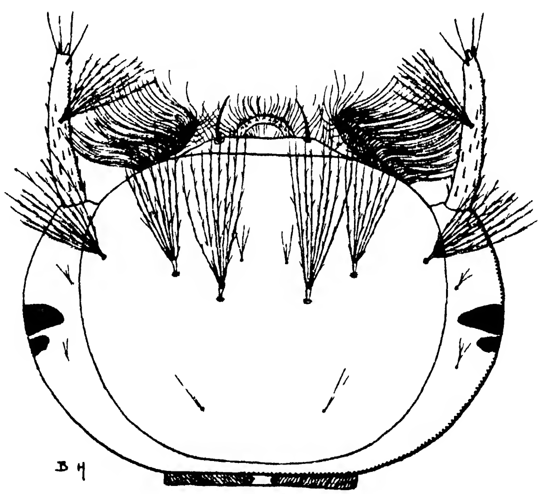

Fig 12. *Culex (Culiciomyia) nebulosus*, Theo., head

species. It is mentioned in Edwards' key to the larvae of African *Culex* (Edwards, 1912, p. 380) but the particulars given are insufficient.

Described from four skins and two whole larvae. Length about 5 mm.; colour grey, head, siphon and anal segment rather dark brown.

Head broader than long (1·2 : 1). Antenna short (about half length of head), not infuscate, densely spiculate ; antennal tuft of about 10 short plumose branches at about 3/5, the tips of these branches reach the tip of the antenna. Clypeal spines rather long and slender. Clypeal setae A, B and C with about 12, 8 and 8 plumose branches respectively, their bases almost in a straight line which forms an angle of about 60° with the long axis of the body ; *d* small, with three simple branches ; *e* small, two-branched. Mentum triangular, on each side of the large median tooth are about 12 teeth, which increase in size basally. *Abdomen* : comb of about 30 approximately equal scales in a roughly semicircular patch, each scale with a long distal fringe. Siphon short (index about 3 : 1) with a prominent acus ; pecten of 4 or 5 strongly denticulate teeth extending nearly to a half ; four pairs of large subventral tufts each with about four subplumose branches, single pairs of shorter lateral

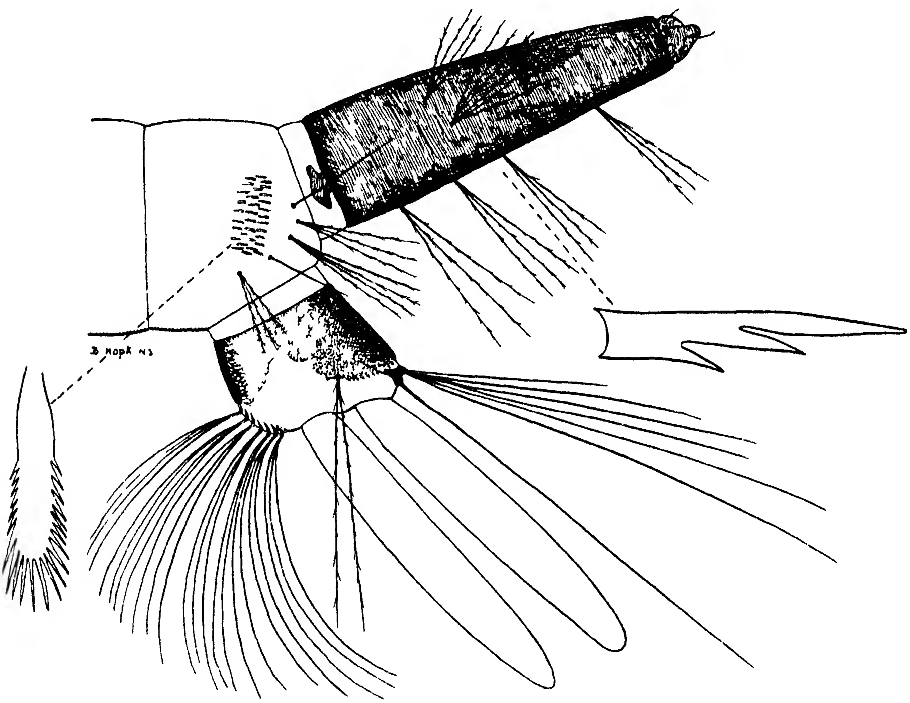

Fig 13 *Culex* (*Culiciomyia*) *nebulosus*, terminal segments of abdomen.

and subdorsal tufts each with four or five simple branches. Anal segment well chitinised, distal margin of saddle rather strongly spiculate, upper dorsal seta with about six simple branches graduated in size from above down, the lowest branch being the longest ; lower dorsal seta single, simple, about five times length of anal segment ; lateral hair double, minutely plumose, very long (2·5 times length of anal segment). Ventral fin feebly developed, composed of four or five pairs of tufts with simple branches. Anal gills very large, sausage-shaped, equal, more than three times length of anal segment.

The siphonal index of about three immediately distinguishes this species from any other known larvae of Ethiopian *Culex* except *C. cinereus* ; from the latter it is readily separated by the spiculate antennae, the greater number of comb-scales and the different arrangement of the main clypeal setae.

Culex (Culiciomyia) cinereus, Theo. (figs 14, 15).

The larva of this species has been briefly described by Wesché (p 32 as *C free-townensis*, and p 33 as *C cinerea*), the particulars given are not sufficient for its identification

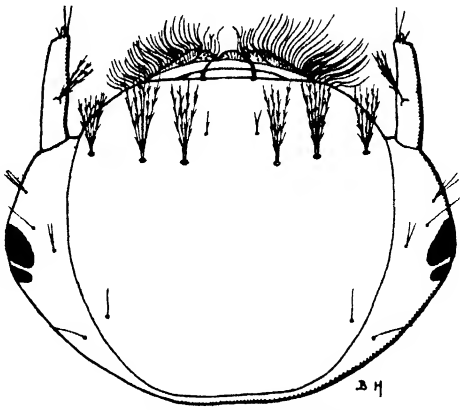

Fig 14 *Culex (Culiciomyia) cinereus* Theo, head

Described from three skins and four whole larvae Length about 5 mm, colour as in *C nebulosus*

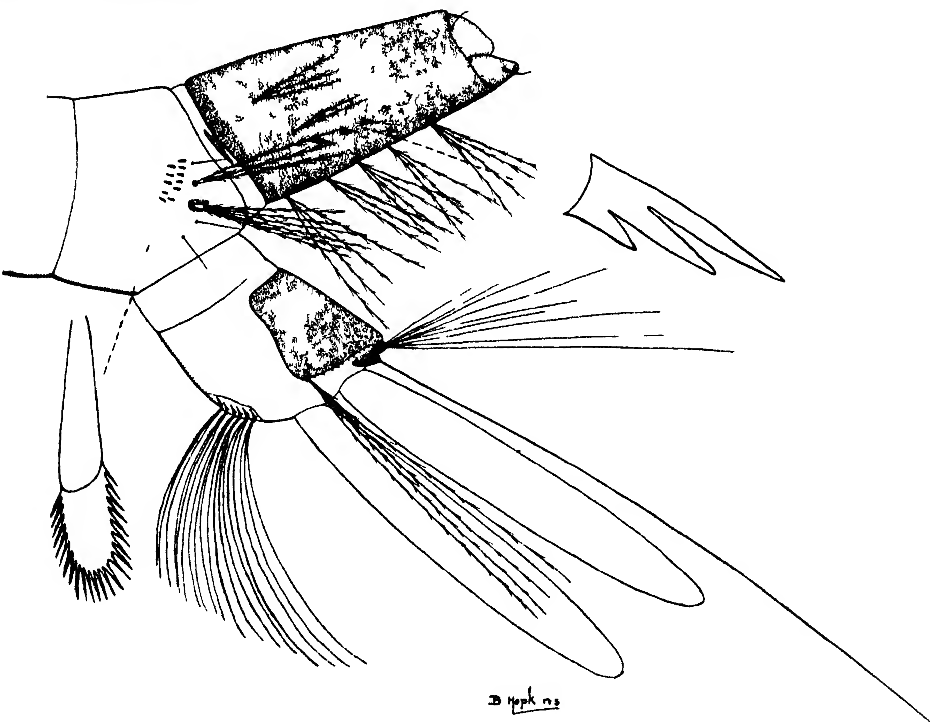

Fig 15 *Culex (Culiciomyia) cinereus*, terminal segments of abdomen

Head broader than long (1·2 . 1) Antenna not infuscate, without spicules, tuft of two to four short subplumose hairs at about 3/5. Clypeal spines similar to

those of *C. nebulosus*. Clypeal setae A, B and C coarsely plumose, A with about 8 branches, B and C with 5 or 6, the bases of these three setae almost in a straight line, which forms nearly a right angle with the long axis of the body; *d* small, with two or three branches; *e* rather long, simple. Mentum similar to that of *C. nebulosus*. *Abdomen*: comb of about 12 (8–14) rather large scales arranged in an irregular patch. Siphon very short (index 2–2·5 : 1), nearly black, with a large acus; the pecten consists of three strongly denticulate teeth and extends to about a third; five large pairs of subventral tufts each with about four plumose branches; single pairs of lateral and subdorsal hairs each with two or three slightly plumose branches. Anal segment strongly chitinised, distal edge of saddle spiculate; upper dorsal seta similar to that of *C. nebulosus*, with about seven branches, lower dorsal seta single; lateral seta with three or four slightly plumose branches, about twice as long as anal segment; ventral fin much reduced, composed of four pairs of tufts each with a very small number of short simple branches. Gills about three times length of anal segment, sausage-shaped, dorsal pair slightly shorter than ventral.

The low siphonal index and the presence of a ventral fin on the anal segment at once separate this larva from all other Ethiopian members of the genus except *C. nebulosus* and *C. hancocki*. From the latter it is readily distinguished by the dark head and siphon and the slightly greater siphonal index; the differences from the former have been given above.

Key to Genera of Ethiopian Mosquito Larvae.

Keys to the genera of the known larvae of Ethiopian mosquitos have been published by Edwards (1912) and Bedford (1928, p. 926). The discovery of larvae unknown at the time these keys were published has rendered them inaccurate, and it has been thought desirable to draw up a new key to include the recently described forms. The characters used in this key are not necessarily applicable to other than Ethiopian larvae.

1. Siphon absent ... ... *Anopheles*
   Siphon present 2
2. Mouth-brushes modified (for predacity) into strong curved spines ... 3
   Mouth-brushes not as above 5
3. Comb and pecten absent; a large chitinous plate on 8th abdominal segment ... ... *Megarhinus*
   Not as above 4
4. Siphonal ratio 1·5 : 1; siphon with numerous long subventral tufts ... *Lutzia*
   Siphonal ratio much more than 1·5 : 1; a single subventral tuft on siphon ... ... *Mucidus*
5. Siphon highly modified for piercing aquatic plants; clypeal setae not longer than head ... ... *Taeniorhynchus*
   Siphon not so modified, or if so, clypeal setae about twice length of head 6
6. Siphon with numerous dorsal or subdorsal tufts of setae ... ... *Harpagomyia*
   Siphon without numerous dorsal or subdorsal setae (a few branched setae may be present but do not form large tufts) 7
7. Siphon usually with numerous subventral tufts, always with more than one such tuft (these tufts may be very small and inconspicuous or consist of single hairs) ... ... *Culex*
   Siphon with only one subventral tuft 8
8. Ventral brush on anal segment absent ... ... *Eretmopodites*
   Ventral brush on anal segment present 9

9.	Antennae very large, flattened laterally; a pair of strong curved spines present at apex of siphon ...	*Aëdomyia*
	Not as above ...	10
10.	Comb on the edge of a chitinous plate; head-setae B and C simple, often very stout and serrate ...	*Uranotaenia*
	Not as above ...	11
11.	Antennal tuft near tip ...	*Hodgesia*
	Antennal tuft at or near middle ...	12
12.	Pecten absent or reduced ...	*Ficalbia**
	Pecten not reduced ...	13
13.	Tuft of siphon very near base ...	*Theobaldia*
	Tuft of siphon at or beyond middle ...	*Aëdes*

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* Mr. Edwards informs me that, in his forthcoming revision of the mosquitos for the Genera Insectorum, *Mimomyia* is reduced to the status of a subgenus of *Ficalbia*.

A STUDY OF THE SANDFLY POPULATION IN ENDEMIC FOCI OF INFANTILE KALA-AZAR IN ITALY.*

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(PLATES VI & VII.)

From the middle of July to the beginning of September 1929 a study was made of the sandfly population in the neighbourhood of Naples and in Catania. These places were chosen because they are the most important centres of visceral leishmaniasis in Italy. Prof. R. Jemma, Director of the University Clinic of Pediatrics in Naples, and Prof. A. Longo, Director of the University Clinic of Pediatrics in Catania, very kindly interested themselves in the work and provided all the necessary facilities. Owing to the data which they generously put at our disposal it was possible to pay particular attention to quarters and houses in which there were actually cases of infantile kala-azar, or where cases had occurred, and to compare the sandfly population with that in other places free from the disease.

We concentrated on sandflies because in our opinion all the available evidence points to the transmission of kala-azar in China and India and oriental sore in other areas by various species of sandflies. Other insects so far suggested as possible vectors can be safely excluded, partly on experimental grounds and partly because their distribution has not the remotest relationship to that of the disease.

The two foci selected are of additional interest, for they contain both human and canine visceral leishmaniasis. In contrast to Assam, where cases in infants under twelve months are very rare, 9·5 per cent. of all the cases in Naples and 13·3 per cent. in Catania are infants under twelve months.

The exact relationship between the human and canine disease has not yet been definitely established by experiment. Cases of infantile and canine visceral leishmaniasis have on several occasions been found in the same house ; but this may be a mere coincidence, for human cases occur in houses where dogs are not affected. The exact distribution of the human and canine disease in a locality where they occur together has not yet been worked out. The occurrence of visceral leishmaniasis in street dogs has been stressed, but there are no statistical data comparing the frequency of the disease in house dogs and street dogs. According to Prof. Longo, destruction of street dogs in Catania in recent years has not affected the incidence of the disease in children.

Canine cutaneous leishmania has been shown to be infective for man, but the relationship between human and canine visceral leishmaniasis is still *sub judice.*

Description of Species.

Five species of sandflies were found :—*Phlebotomus papatasii*, Scop. 1786 ; *P. perniciosus*, Newst. 1911 ; *P. sergenti*, Parrot 1917 ; *P. vesuvianus*, sp. n. ; and *P. parroti* var. *italicus*, var. n.

* Carried out with a grant from Dr. Julius Moses, Mannheim.

Phlebotomus papatasii, Scop.

Abundant everywhere.

Material examined : 1,563 ♀♀, 94 ♂♂, from various localities.

Phlebotomus perniciosus, Newst.

Synonym : *P. grassii*, Dierantoni 1924.

Grassi's original description of *P. mascittii* corresponds very closely with Newstead's description of *P. perniciosus*. Newstead examined one of Grassi's co-types and differentiated it from *P. perniciosus* on the following characters :—(1) *P. perniciosus* bears five spines on the distal segment of the superior clasper, *P. mascittii* one small and five large spines ; (2) in *P. mascittii* the upper branch of the second vein is 2·5 times as long as the vein between the forks, in *P. perniciosus* 1·5 times as long ; and (3) size of *P. mascittii* 3·5 mm., of *P. perniciosus* 1·8–2·6 mm.

According to Newstead the male genitalia of Grassi's co-type of *P. mascittii* differ from those of *P. perniciosus* in that they show in addition to the five usual spines one very thin spine at about the middle of the segment (this is probably an abnormally situated hair). In this respect it differs from all known species of the *major* group. A sixth spine has been recorded as an abnormality in various species, *e.g.*, in *P. papatasii*,

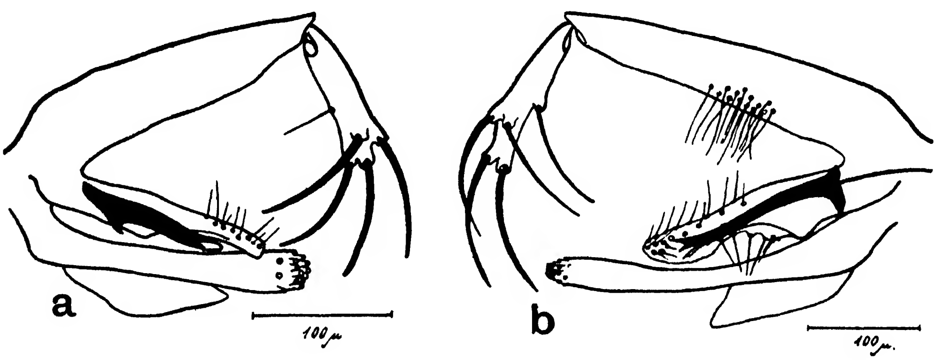

Fig. 1. Male genitalia of : (*a*) *Phlebotomus parroti* var. *italicus* ; (*b*) *P. perniciosus*.

a typically five-spined species. *P. mascittii*, as described by Grassi, belongs to a large group of sandflies including *P. argentipes*, *P. major*, *P. chinensis*, etc., all of which have five spines on the distal segment of the superior clasper. Out of a very large collection of sandflies made near Naples and in Catania we found many specimens corresponding to Grassi's description of *P. mascittii* and Newstead's description of *P. perniciosus*, and not a single male with six spines. As it appeared essential to determine the systematic position of *P. mascittii* and *P. perniciosus*, a collection of sandflies was made in Rome. Grassi's original collection is no longer existent, but owing to the kindness of Mr. E. Mascitti, Grassi's former assistant, sandflies were collected in the same house from which Grassi obtained the material on which he based his description of *P. mascittii*. This house is situated in a very large garden and is isolated from other habitations. The only species found there by the late Prof. Grassi was *P. mascittii*. The breeding place was a cellar where Mr. Mascitti had found larvae in the ground. We collected 12 sandflies, 8 ♂♂ and 4 ♀♀, and they all belonged to the same species. All showed genitalia corresponding to Grassi's original description, and not a single one had six spines. It is therefore likely that *P. perniciosus*, Newstead, is a synonym of *P. mascittii*, Grassi, but this point cannot be settled until the co-type is re-examined.

♀. *Size*: 1·8–2·4 mm. *Palp formula*: 1, 2, 4, 3, 5 or 1, (4, 2), 3, 5 or 1, 4, 2, 3, 5; segment 3 always markedly longer than 2 or 4. *Antennae*: segment 3> +5. *Wings*: length, 1·65–2·1 mm.; breadth, 0·47–0·6 mm.; index, $\alpha/\beta=1{\cdot}15$–$1{\cdot}9$. *Pharynx* similar to that of *P. major*. It has been described and figured in previous papers. Posteriorly it has almost parallel transverse rows of fine dots. In some specimens the middle teeth are coarser than the lateral ones. In one female an abnormal pharynx was observed. It showed a constriction in front of the toothed area. The teeth are typical for *P. perniciosus* (Plate vi, fig. 2). *Spermathecae* consisting of 11 to 13 segments surmounted by a long neck terminating in a small round head. The ducts are fairly wide and feebly chitinised.

♂. Size, palps, antennae and wings as in the female. *Pharynx* similar to that of the female, but narrower posteriorly and the teeth less marked. *Genitalia* (text-fig. 1, *b*): the distal segment of the superior clasper with the five spines characteristic of the *major* group: two terminal, a slightly thinner one at about the middle of the segment, and two others (one strong and one thinner) half-way between the terminal and the proximal spines. The intermediate appendage rather stout, having a club-shaped head and a well-marked short neck, which bears a number of fine bristles. The intromittent organ slender, slightly curved and with the extremity bifid, both points of the fork being equally sharp. The inferior clasper as long as, or slightly longer than, the superior one.

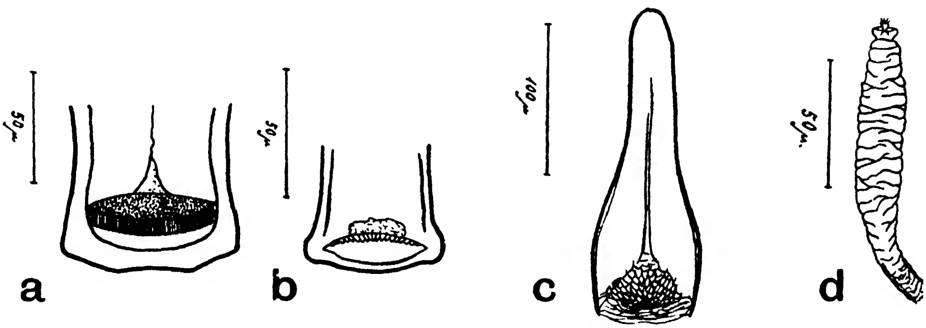

Fig. 2. *Phlebotomus parroti* var. *italicus*, buccal cavity of: *a*, female; *b*, male. *P. vesuvianus*, female: *c*, pharynx; *d*, spermatheca.

Material examined: Bosco Trecase, 504 ♀♀, 152 ♂♂; Catania, 157 ♀♀, 14 ♂♂; Rome, 8 ♂♂, 4 ♀♀; Naples, 3 ♀♀, 3 ♂♂; Capo di Monte, 6 ♀♀, 2 ♂♂; Positano, 2 ♀♀; Portici, 1 ♀, 1 ♂; Ottajano, 1 ♀.

Phlebotomus parroti var. **italicus** var. n.

♀. *Size*: 1·7–2 mm. *Palp formula*: 1, 2, (4, 3), 5 or 1, 2, 4, 3, 5; segment 2 slightly longer than half of segment 3. *Antennae*: 3<4+5. *Wings*: length, 1·8 mm.; breadth, 0·37–0·4 mm.; index, $\alpha/\beta=0{\cdot}5$–$0{\cdot}7$. *Buccal cavity* (Plate vii, fig. 2, & text-fig. 2, *a*): the teeth, about 50 in number, are parallel, arranged like a palisade, and stand on an arc slightly convex posteriorly. The pigmented area is a transverse elongated ellipse stretching across the whole breadth of the buccal cavity. *Pharynx* lamp-glass-shaped; on the posterior part of the lateral plates there are teeth which point backwards. In general outline it is similar to that of *P. africanus*. *Spermathecae* tubular, as in *P. minutus*.

♂. Size, palps, antennae and wings as in the female. *Buccal cavity* (text-fig. 2, *b*): the teeth are much fewer, less marked than in the ♀, pointed posteriorly and converge towards the middle line. There is sometimes a faint pigmented area with an irregular elliptical outline. *Pharynx* similar to that of the female but narrower, with less

marked teeth. *Genitalia* (text-fig. 1, *a*) of the *minutus* type. The distal segment of the superior clasper is slightly less than half the proximal segment and bears two terminal and two subterminal spines; a fine anterior spine is situated somewhat below the middle of the segment. The intermediate appendage ends in a blunt head. The intromittent organ is rather stout and tapers towards the apex.

Material examined: Bosco Trecase, 37 ♂♂, 13 ♀♀; Catania, 5 ♀♀, 5 ♂♂; Capo di Monte, 1 ♀; Ottajano, 1 ♀; Resina, 7 ♂♂; Ischia, 2 ♂♂.

The variety described here differs from the typical form mainly in the number of teeth in the buccal cavity, which are fewer (70–80 in *P. parroti*) and coarser.

P. parroti var. *italicus* is the only species of the *minutus* group that we have found so far in Italy. It is therefore possible that this is the real *P. minutus* of Rondani. Sinton, who re-examined Newstead's specimens from Malta, found them to correspond with our description of *P. minutus*. As the sandfly fauna of Sicily and South Italy is rather similar to that of Algeria and Malta, where *P. minutus* is very common, this species will possibly be found in Italy also. We therefore leave this question open, especially as Rondani's types are not available. *P. parroti*, which was originally described from Algeria, and its variety *italicus* have since been identified in material from Spain and Tunis. It has apparently a wide distribution in the Western Mediterranean.

Phlebotomus **vesuvianus**, sp. n.

♀. *Size*: 2·8–3·4 mm. *Palp formula*: 1, 4, (2, 3), 5. *Antennae*: 3> 4+5. *Wings*: length, 2–2·3 mm.; breadth, 0·65–0·75 mm.; index, $\alpha/\beta=2{\cdot}4$–$2{\cdot}6$. *Pharynx* (Plate vii, fig. 1, & text fig. 2, *c*): posteriorly a number of rather coarse teeth with their axis pointing towards the middle of the posterior margin; the anterior limit of the toothed area is rounded. The general arrangement resembles that of *P. chinensis*, but the teeth are broader and fainter. *Spermathecae* (text-fig. 2, *d*) in general outline similar to those of *P. chinensis*. They are elongated feebly chitinised tubes, showing incomplete segmentation. The superior end is rather broad, not tapering as in *P. chinensis*, and surmounted by a small protrusion bearing a little knob.

♂. Unknown.

Material examined: Bosco Trecase, 7 ♀♀; Capo di Monte, 6 ♀♀.

This species clearly belongs to the *chinensis* group, for it resembles *P. chinensis* in palp formula and wing venation. The pharynx and spermathecae also have the characteristics of this group but differ constantly in some details.

Phlebotomus sergenti, Parrot.

This species has been sufficiently described in previous papers. The specimens found agree in every detail with those from Algeria and Mesopotamia. It was found only in Catania (5 ♀♀, 5 ♂♂).

Observations on the Habits of P. perniciosus.

Roubaud found that this species feeds more readily on man than on laboratory animals. In South Italy it appears to be distinctly zoophilic; wherever there is a stable in the neighbourhood of a house far more gorged specimens of *P. perniciosus* are found in the stable than inside the house. In several cases we found human sleeping rooms and stables connected by open windows or doors, and in each instance the number of *P. perniciosus* in the stable was many times greater than that in the sleeping rooms at all times of the day.

P. perniciosus feeds mainly in the early evening, and unless suitable shelter is available it does not remain very long in the room where it has fed. In our catches, which we carried out two or three times a day, the number of *P. papatasii* did not

vary very much except that it was much more difficult to catch the active insects in the evening. The number of *P. perniciosus* was considerably less in the morning than in the evening, when they come out to feed. They are apparently more photophobic than *P. papatasii.*

Between 8 and 9 p.m. fully gorged females of *P. perniciosus* could be found sitting low down on the walls in the rooms where they had fed. Later in the evening (about 11 p.m.) only a few were found in corners or cracks. Several specimens were found outside the house in sheltered dark corners, and more were found in a dark cellar adjoining a house.

Distribution of Sandflies and Infantile Kala-azar.

A total of 2,600 sandflies were caught, of which 331 were males ; 1,547 females were dissected from the following localities :—

P. papatasii : 577 ♀♀ from Bosco Trecase, 648 ♀♀ from Catania, 41 ♀♀ from infected villages near Naples.

P. perniciosus : 117 ♀♀ from Bosco Trecase, 153 ♀♀ from Catania.

P. parroti var. *italicus* : 4 ♀♀ from Bosco Trecase.

P. vesuvianus : 2 ♀♀ from Bosco Trecase.

P. sergenti : 5 ♀♀ from Catania.

The remainder were used for breeding and were subsequently examined after clearing and mounting in Canada balsam.

The numbers of sandflies examined apart from those dissected were :—

	Males	Females
P. papatasii	94	297
P. perniciosus	181	399
P. parroti var. *italicus*	51	20
P. sergenti	5	—
P. vesuvianus	—	10

The figures given above do not necessarily give an accurate indication of the relative frequency of the species ; *e.g.*, the percentage of *P. perniciosus* is probably much too high, for special attention was paid to places known to be rich in this species. On the other hand, *P. papatasii* is much easier to catch and remains for a longer time than *P. perniciosus* in the room where it has fed.

Among the 1,547 females dissected not a single one was found to be infected with *Leishmania.* This, however, does not tell against the sandfly theory of the transmission of infantile kala-azar. In this disease Leishman-Donovan bodies are rare in the blood. Cultures can usually be obtained from cases by the inoculation of 0·1 cc. of blood into a tube of Locke-blood-agar. This amount of blood represents a full feed for a large number of sandflies. The infection rate in any sandfly vector would necessarily be very low. Cases examined by blood culture are usually advanced, and there is at present very little information available as to the frequency of parasites in the blood in the early stages of the disease.

An analysis of the species caught in kala-azar houses and in houses free from the disease did not give conclusive evidence as to the species of the vector. *P. papatasii* and *P. perniciosus* were found together both in houses with cases of the disease and in others where no cases had occurred. In Catania, as in Naples, cases of infantile kala-azar occur mainly at and near the periphery of the town, and there are comparatively few cases in the centre of the town. In both places *P. papatasii* and *P. perniciosus* are far more numerous near the outskirts of the town, where they are the commonest biting insects, than in the centre of the town. *Phlebotomus vesuvianus* can be suspected as a carrier only because of its close relationship to *P. chinensis.*

Its distribution does not correspond with that of the disease, for it was not found in Catania. Its rarity does not preclude it from being a carrier, for as stated in a previous paper: "The distribution of visceral Leishmaniasis in the Mediterranean basin suggests that the disease is either transmitted by a species of insect which is common and widely distributed but is not an efficient vector, or that it is transmitted by an efficient vector which is comparatively rare and irregularly distributed, possibly *P. chinensis.*"

P. parroti can be excluded as a possible vector of the disease, for it seldom if ever bites man and feeds mainly on lizards.

The Behaviour of Italian Strains of Leishmania donovani in Sandflies.

In a previous communication (1927) it was pointed out that sandflies (*P. papatasii*) could be infected with *Leishmania* by feeding them through membranes on emulsions of culture in inactivated rabbit blood. The behaviour of two Mediterranean strains was recorded; one strain ascended into the buccal cavity, and the other remained in the midgut. During 1928 and 1929 we had the opportunity of examining several strains from Naples cultured directly from human cases. In addition, one dog was inoculated from two human cases and transported to Jerusalem, where a culture was obtained from the liver. The strains taken from human beings and the strain isolated from the dog were found to be non-infective for mice by inoculation into the tail.

A number of sandflies were fed through membranes on cultures of several strains. The following table shows the behaviour of these strains in *P. papatasii.*

TABLE I.

The Behaviour of Italian Strains of L. donovani *in* P. papatasii.

Strain	Age of culture in days	No. of flagellates per 0·1 cmm.	No. of sandflies fed	Total no. positive	No. of days after feed	No. dissected	No. positive	Remarks
Dog ...	11	400	12	1	9	1	1	Cardia and stomach infected. Remainder of sandflies dissected from 4 to 21 days after the feed, negative.
Dog ...	18	700	9	1	12	1	1	Heavy infection in cardia and stomach. Cardia choked with flagellates. Remainder of sandflies dissected from 3 to 12 days after the feed, negative.
Human strain I	11	100	13	0	—	—	—	Dissected from 4 to 13 days after the feed.
Human strain I	10	800	9	1	4	9	1	Infection in stomach. Contaminated with bacteria. Other sandflies dissected negative and clean.
Human strain II	6	800	25	6	12	2	1	Mass of flagellates in cardia and stomach.
					18	3	1	Cardia and stomach infected. Cardia choked with flagellates.
					19	2	1	As above.
					24	1	1	As above.
					27	3	1	As above.
					30	2	1	As above.
								Remainder of sandflies dissected from 3 to 23 days after feed, negative.

P. perniciosus (laboratory bred) refused to feed through membranes. The results shown in Table I suggest that *P. papatasii* is not a good carrier of the strains used in our experiments. The carrier would be expected to give a much higher infection rate with the above concentrations of flagellates, which represent far more parasites per feed than would be obtained in nature. Some Palestinian strains of *L. tropica* give almost a 100 per cent. infection rate in *P. papatasii* fed on much poorer concentrations. The observations made in our survey point mainly to two possible sandfly carriers, namely *P. papatasii* and *P. perniciosus*. The results obtained with *P. papatasii* suggest that *P. perniciosus* is a more likely carrier.

TABLE II.

The Behaviour of Indian Strains of L. donovani *in* P. papatasii.

Strain	Age of culture in days	No. of flagellates per 0·1 cmm.	No. of sandflies fed	Total no. positive	No. of days after feed	No. dissected	No. positive.	Remarks
No 1 ...	9	600	17	4	8	4	3	In one cardia and stomach infected. In two only the stomach.
					9	7	1	Infection in cardia and stomach. Remainder of sandflies dissected from 2 to 10 days after feed, negative.
No 1 ...	9	1,200	7	3	4	2	2	Both infected in stomach only.
					5	1	1	As above. Remainder dissected 6 days after feed, negative.
No. 1 ...	7	800	11	5	6	1	1	Infection in stomach.
					7	3	3	As above.
					10	3	1	As above. Remainder dissected 11 days after feed, negative.
No 1 ...	9	250	12	4	5	1	1	Slight infection in stomach.
					8	2	2	As above.
					10	3	1	As above. Remainder dissected from 9 to 11 days after feed, negative.
No. 1 ...	10	1,500	21	12	2	1	1	Infection confined to stomach.
					3	1	1	As above.
					5	1	1	As above.
					6	1	1	As above.
					7	3	3	In one cardia and stomach infected, in two infection confined to stomach.
					8	8	4	Infection confined to stomach.
					9	3	1	As above. Remainder of sandflies dissected 10 days after feed, negative.
No. 2 ...	3	560	4	0	—	—	—	Dissected 6 days after feed.
No. 2 ...	8	450	20	6	6	9	6	In two cardia and stomach infected, in four infection confined to stomach.

We did not succeed in feeding *P. perniciosus* on experimentally infected dogs. Using Hertig's method for feeding single sandflies through capillaries we succeeded

in infecting *P. perniciosus* var. *tobbi* (laboratory bred) from Palestine with two Mediterranean strains of *L. donovani*, one from Haifa cultured from the blood of a child and one from Naples which had been passed through a dog and cultured. Both strains produced a low infection rate in *P. papatasii*. In *P. perniciosus* var. *tobbi* both strains ascended the cardia even when the infection was slight. These strains are apparently better adapted to *P. perniciosus* var. *tobbi* than to *P. papatasii*. In India *P. papatasii* is certainly not the main carrier of kala-azar. In feeding experiments on cases of kala-azar carried out in India by Napier & Smith (1927) the infection rate in *P. papatasii* was 2 per cent. as against 43 per cent. in *P. argentipes* fed on the same cases. Nevertheless, as Table II shows, two strains of *L. donovani* from India produced a higher infection rate than the Italian strains in *P. papatasii* (37 per cent. of the sandflies became infected with the Indian strains and 13·2 per cent. with the Italian strains). The intensity of the infection was much higher in the case of the Italian strains. The cardia was choked with flagellates in 8 out of 9 sandflies infected with the Italian strains, while only 5 out of 34 positive sandflies infected with the Indian strains showed a moderate infection in the cardia. There was another important difference between the two: namely, infections with the Indian strains tended to die out progressively in the sandflies, but this phenomenon did not occur in the case of the Italian strains.

Both strains differed from a canine strain of visceral leishmaniasis received from Prof. Nicolle, Tunis, in that the latter produced a high infection rate in *P. papatasii* and the parasites ascended into the pharynx. This strain is particularly infective for mice, in which it produces local lesions after inoculation into the tail. We also succeeded in producing local lesions in a human being by inoculating material from the tail of an infected mouse. Neither the Indian nor the Italian strains produced local lesions in mice.

Summary.

The sandflies of the two largest Italian foci of visceral leishmaniasis, Naples and Catania, were studied.

The following species were found: *P. papatasii, P. perniciosus, P. sergenti, P. vesuvianus*, sp. n., *P. parroti* var. *italicus* var. n.

P. papatasii and *P. perniciosus* are the commonest sandflies in the areas examined.

Out of 1,547 ♀♀ dissected none showed a natural infection with *Leishmania*.

P. papatasii was infected with Italian strains of *L. infantum* by feeding on cultures through membranes. The infection rate was low, but in contrast to Indian strains of *L. donovani* in the same sandfly, the infection once established did not die out.

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Fig · *P perniciosus*

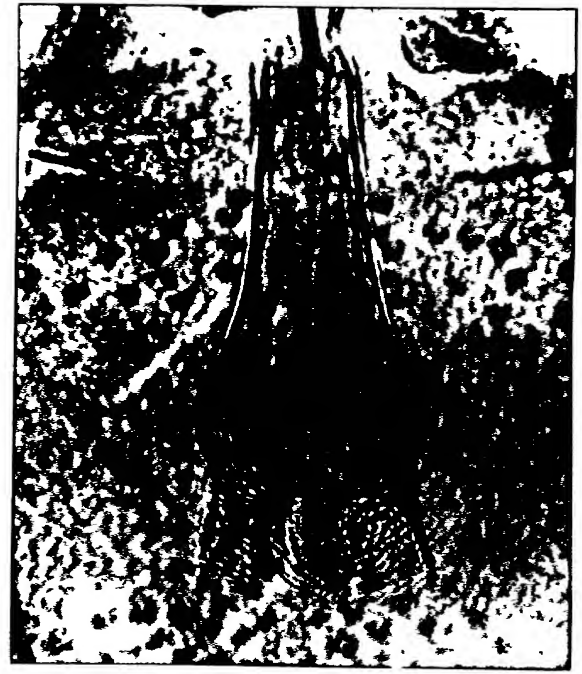

Fig · *P perniciosus* (a) normal

Pharynx of Female Phlebotomus (x 350)

Fig. 1. *P. esutranus* × 350.

Fig. 2. *P. parroti* with buccal cavity × 400.

Pharynx of Female Phlebotomus.

NEW TRYPETIDAE (DIPT.) FROM SOUTH AFRICA, II.

By H. K. Munro, B.Sc., F.E.S.

The following descriptions are based on material collected or reared by the author, together with specimens reared from host-plant material collected by colleagues to whom the author's thanks are due.

From the descriptions it will be further evident that the generic location of new species is still difficult, but this state of affairs can only be remedied by a monographic revision of the African Trypetidae. It is felt, however, that although the author has such a work in progress, it is not desirable to hurry publication. Delay is advisable, especially in view of the number of new species continually being found, and the frequent need for the formation of new genera.

Types of the new species are in the author's collection; paratypes so far as available will be placed in the British Museum.

Urophora petiolata, sp. n. (fig. 1).

A very small black species with head and legs mainly yellow and hyaline wings.

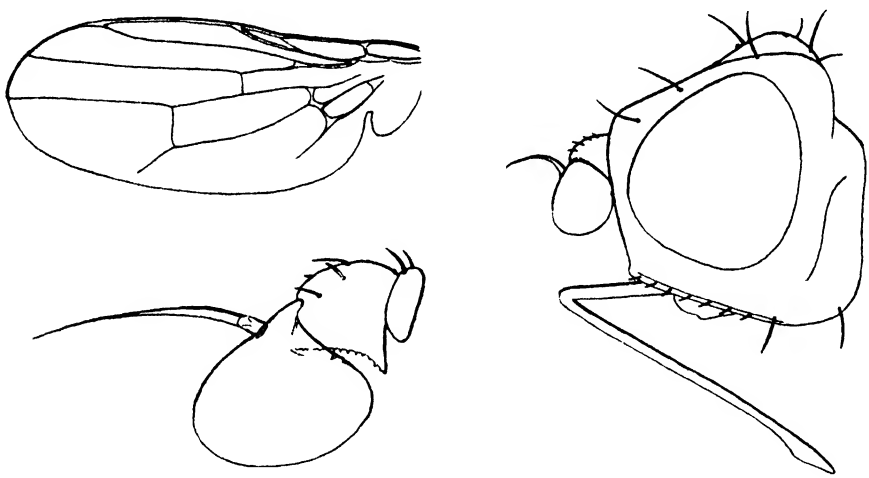

Fig 1 *Urophora petiolata*, sp n, wing, antenna and head.

It is somewhat difficult to decide in what genus to place the following two new species. They are closely related to those included by Bezzi under *Urophora* in the Bulletin of Entomological Research, xv, p. 116. Hendel states, however, that *Urophora* is a synonym of *Euribia*, and he places in this latter genus, and in *Myiopites*, those European species apparently related to the above-mentioned African species. On comparison with Hendel's definition of *Euribia*, the species *petiolata* would seem to belong to the subgenus *Asimoneura*, although there appears also to be a close relationship to *Myiopites*. There is one character, however, that excludes *petiolata* not only from *Euribia* and *Myiopites*, but from Hendel's Euribiini as a whole, namely, the fact that the sixth abdominal segment in the female is slightly longer than the fifth. In spite of this, I think the species undoubtedly belongs to the Euribiini, as it agrees in all other characters listed by Hendel (Pal. Dipt. Trypetidae, p. 17). On the whole a new genus may be required for the African species, but

before deciding on this a closer examination of both European and African forms is desirable. Hence this and the following species have been placed in *Urophora* for the meantime, at least for the sake of immediate continuity with Bezzi's work.

The differences and relationships between the two new species and those included by Bezzi in *Urophora* are shown in the following table :—

1 (2). Wings with a distinct, partly banded pattern ... ... *hemixantha*, sp. n.

2 (1). Wings without pattern.

3 (4). Proboscis short and simple ; scutellum yellow ; third and fourth veins converging at end ... ... *vernoniicola*, Bez.

4 (3). Proboscis long and geniculate ; scutellum black ; third and fourth veins parallel or very slightly diverging at end.

5 (8). Labella shorter than base of head ; all femora black.

6 (7). Labella quite short, proboscis not projecting either in front or behind ; head mainly yellow ... ... *agromyzella*, Bez.

7 (6). Labella almost as long as base of head, and, with palpi, slightly projecting in front ; head black ... ... *pantomelas*, Bez.

8 (5). Proboscis very long, labella longer than base of head and projecting at least behind ; front legs always yellow.

9 (10). Proboscis not projecting beyond epistome, which is somewhat prominent ; third antennal joint apparently of normal shape ; ovipositor as long as abdomen ; larger species, 4·5 mm. ... ... *indecora*, Lw.

10 (9). Proboscis projecting in front of and behind head ; third antennal joint short and broad, rounded ; epistome flat ; ovipositor half length of abdomen ; smaller species, less than 2 mm. ... ... *petiolata*, sp. n.

a. antennae and legs all yellow ... ... *flava*, var. n.

b. antennae yellow ; hind femora always blackened, middle femora yellow or blackened ... ... *seminigra*, var. n.

c. third joint of antennae black ; four hind femora blackened *petiolata* (typical).

The species *Urophora cilipennis*, Bez., has been excluded as it has not been described.

♂♀. Length of body and of wing 1·75 mm.

Head (fig. 1) as long as high and slightly wider ; frons wide, twice width of an eye, as long as wide and slightly narrowed anteriorly, flat in most specimens, but in some, apparently better preserved, rather swollen in front, bare, often more or less brownish, always black along vertex, sometimes yellow on anterior half and brown behind, occasionally with yellow or golden dust on the brown ; the yellow may grade into the brown or there may be a well-defined dividing line ; in the forms with blackened antennae the posterior half of the frons is also more usually blackened ; paler along parafrontals where there is a little black pubescence ; vertical triangle black, merging into colour of frons ; two inferior orbitals, one superior orbital, ocellars well-developed ; lunule arcuate, reddish or brownish ; antenna (fig. 1) short, yellow, third joint sometimes black ; first joint short, with a couple of setae above ; second joint more or less quadrate in profile, rounded, with a few setae above, lower inner corner acute and lower edge roughly serrate ; third joint flattened, in profile short and broadly oval with a short triangular base, on inner side of base is a cavity into which the lower corner of the second joint fits, microscopically pubescent ; arista arising from a slight depression on upper side of base of third joint, black, tapering from thickened base and microscopically pubescent ; face short, yellow, concave, with strong lateral ridges and a broad flat median ridge ; epistome

flat ; cheeks and jowls shining yellow to bottom of eye or somewhat farther backwards ; cheeks narrow, half width of jowls, which are two-thirds width of third antennal joint ; a row of fine black setae along peristomalia ; proboscis yellow, linear, very elongate and geniculate, haustellum one and a half times, and labella twice, or nearly twice, length of base of head, when at rest projecting beyond epistome as well as behind head ; mouth-opening large, circular ; palpi linear, yellow ; eye about as long as high, slightly oval ; occiput shining black, rather swollen, especially below, concave in middle above where there is some white dust ; occipital bristles small, black.

Thorax entirely rather dull black, with slight grey to yellow dust ; there is generally a slight indication of a notopleural stripe from humeri to wing-base, which is also usually of a yellowish tinge ; humeri occasionally slightly yellowish. Chaetotaxy normal, bristles brownish black ; dorso-centrals much behind suture and slightly before line of anterior supra-alars ; on front of dorsum is an irregular median row of setae, and two lateral rows, more defined, on line of and reaching to dorso-central bristles ; laterally there are a few scattered setae about suture. Scutellum normal, with four bristles of equal length. Halteres sulphur-yellow. Legs normal. Front femora with row of bristles below. Front legs always yellow, except last two tarsal joints blackened ; middle and hind legs varying from yellow to mainly black. Wings (fig. 1) hyaline, without pattern ; stigma yellow ; veins yellow at base of wing to line from stigma to end of anal cell, becoming brown beyond this ; setae along costa black, no costal bristle ; second vein long ; anterior cross-vein before middle of discal cell ; lower cross-vein perpendicular, as long as half its distance from upper cross-vein ; ends of third and fourth veins parallel or very slightly divergent ; lower angle of anal cell a right angle ; sixth vein not reaching wing margin.

Abdomen dull black, with slight cinereous dust on tergites and very slight indication of yellowish hind margins to last three or four segments, most pronounced on the last. In the male the tergites are narrow ; the second, larger than the others, is as wide as base of scutellum, the third, fourth and fifth one-quarter narrower ; tergites clothed with fine black pubescence, which is bristle-like on sides and round end of last segment ; lateral membranes very strongly developed ; genitalia shining black. In the female the tergites are of about normal width, the second being rather wider than the rest ; the lateral membranes not so strongly developed as in male, but nevertheless conspicuous. The sixth segment is as long as or rather longer than the fifth. Ovipositor half length of abdomen ; shining black, with black pubescence ; robust, conical, slightly flattened at end.

In contrast with the two varieties described below, the typical form presents the following distinctions :—

Third antennal joint black ; legs yellow with last two joints of all tarsi black ; middle coxae black at base and femora broadly black in middle ; hind coxae and femora, except distal ends of latter, black.

ORANGE FREE STATE : Fauresmith, 11 ♂♂, 12 ♀♀ (including types), i.–ii.1930 (*H. K. Munro* and *S. J. S. Marais*). With these are associated 4 ♂♂ and 5 ♀♀ in which the third antennal joint is only brownish, and in one male the middle femora almost quite yellow. These are all from Fauresmith, i.1930, except one male from Hanover, Cape, i.1930.

U. petiolata var. **flava**, n.

Antennae yellow, arista black ; legs yellow except middle coxae at base, and hind coxae entirely, black, and last two joints of all tarsi blackened, occasionally yellow or only brownish ; in the female they are usually darker than in the male or even black.

Cape Province : Craigieburn, Herbert district, 8 ♂♂, 3 ♀♀ (including types), iii.1928 (*H. K. Munro*). Orange Free State : Fauresmith, 3 ♂♂, 4 ♀♀, i.–ii.1930 (*S. J. S. Marais*).

U. petiolata var. **seminigra,** n.

Antennae yellow, arista black ; legs yellow with last two joints of front tarsi darkened, middle coxae blackened at base, femora yellow or broadly blackened in middle, and last two tarsal joints blackened, hind coxae, femora (except apices), and last two tarsal joints black.

Orange Free State : Fauresmith, 8 ♂♂, 4 ♀♀ (including types), ii.1930 (*S. J. S. Marais*). Cape Province : Craigieburn, Herbert district, 3 ♂♂, 2 ♀♀, iii.1928 (*H. K. Munro*) ; Hanover, 1 ♂, 1 ♀, i.1930 (*H. K. Munro*).

The foregoing descriptions are based on 69 specimens (a few of which are in alcohol) from three localities, and the numbers from each locality are : from Fauresmith, 7 *flava*, 13 *seminigra* and 27 typical ; from Craigieburn, 12 *flava* and 4 *seminigra* ; from Hanover, Cape, 2 *seminigra* and 1 typical. From these figures it would appear that the typical form is more predominant at Fauresmith, and *flava* at Craigieburn, a hundred miles or so westwards. Whether or not this is any indication of the actual distribution of the varieties only further collecting can show.

From the material examined, the varieties seem to be fairly constant, as intergrades are relatively few, the more noticeable being those in which the antennae are brownish rather than black. That they cross with one another is undoubted, but it is possible that the yellow and black colours of the antennae and legs are characters that behave in a Mendelian fashion, even if the varieties may be merely considered as cases of progressive melanism. It may be noted that no specimens were found having the third antennal joint black and the legs all yellow.

Biology. The larvae live and pupate in the thick bases of the flower-heads of *Pentzia incana* (Compositae), commonly known as the Vaal Karroo Bos. The flower-heads are small, somewhat spherical and not more than 10 mm. in diameter. Usually from two to five puparia were found in each head, but at Craigieburn, where the heaviest infestation was observed, there were often as many as a dozen, which is remarkable in spite of the small size of the larvae and puparia. *Pentzia incana* occurs over a wide area of the Karroo, and *Urophora petiolata* probably occurs wherever its host-plant is. Puparia were observed in flowers at various points in the Fauresmith and neighbouring districts, but unfortunately no adults were obtained.

Urophora hemixantha, sp. n. (fig. 2).

For similar reasons to those given under *Urophora petiolata*, this species is also retained in *Urophora*. It could perhaps be placed in *Myiopites* ; it has a wing pattern like that of *Myiopites blotii*, Breb., to which species indeed it seems to have some resemblance. The first posterior cell, however, is not so narrowed at the end, and, in addition, the sixth abdominal segment in the female is longer than the fifth. It may also be remarked that *hemixantha* has a considerable resemblance to *Ensina sonchi*, L., and it might even be included in *Ensina* as restricted by Hendel. *Ensina* has three inferior orbital bristles, but as will be noted, while some specimens of *hemixantha* have two, others have three. From another point of view, it might be suggested that *Ensina* is more closely related to the Euribiini than is evident from Hendel's classification, a fact noted by Hendel himself.

Urophora hemixantha differs from other species placed in the genus in having a well-defined wing pattern.

♂. Length of body 2·4 mm., of wing 2·2 mm.

Head yellow, length 1 mm., height 1·3 mm., width 1·5 mm. ; frons rather swollen, slightly longer than wide, narrowed a bit anteriorly, twice width of an eye at vertex, bare with only a little black pubescence on fore part of parafrontals, two inferior orbital bristles (three on one side in one specimen), one superior orbital, ocellars well-developed, post-verticals small ; ocellar dot black ; lunule honey-yellow, slightly sunken ; antennae yellow, normal, shorter than face, third joint parallel-sided and with broadly rounded apex ; arista thickened at base, brown (except extreme base yellow) ; face yellow, short, concave with lateral ridges and flat median ridge ; cheeks and jowls shining yellow, cheeks half and jowls slightly wider than third antennal joint (in the specimen from Witdraai, cheeks and jowls are both as wide as the third antennal joint) ; genal bristle and row of setae along peristomalia present ; mouth-opening moderately large, epistome slightly projecting ; proboscis yellow, linear, geniculate, projecting beyond epistome, haustellum as long as base of head, labella a little longer ; palpi yellow, leaf-like, but not very linear ; occiput slightly concave, shining black but more or less broadly margined with yellow above and below.

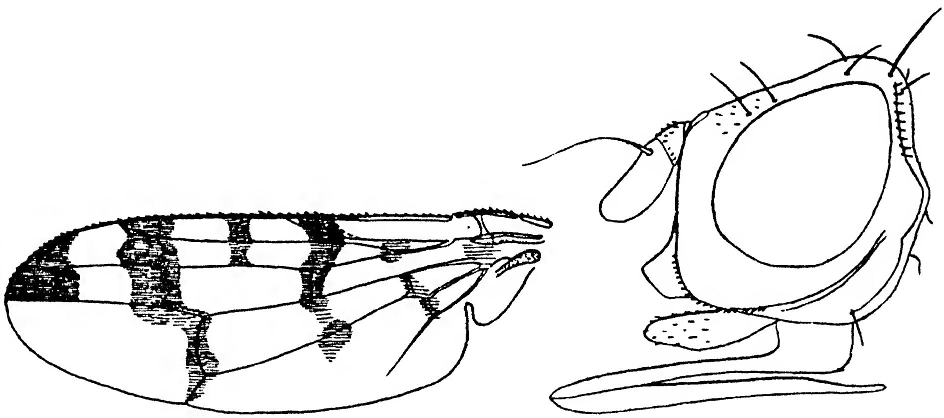

Fig. 2. *Urophora hemixantha*, sp. n., wing and head of female.

Thorax normal, dull black with slight grey dust more pronounced on dorsum ; humeri and a fairly broad notopleural stripe which broadens to wing-base and more or less faintly upwards to include posterior notopleural bristle, yellow (in the Witdraai specimen the yellow colour is more pronounced, and the notopleural stripe is very broad, covering the upper half of the mesopleura, extending narrowly down mesopleural suture and broadly upwards to include the posterior notopleural bristle) ; prosterna and a couple of small spots before the base of halteres also yellow ; bristles normal, black ; cervicals present ; dorso-centrals on line of anterior supra-alars. Legs honey-yellow, last one or two joints of all tarsi blackened, front coxae lemon-yellow and with two bristles on anterior surface towards distal end ; front femora with usual row of bristles below ; vestiture of legs black. Halteres yellow. Scutellum yellow, outer corners broadly black (in the Witdraai specimen the yellow is more extended) ; four bristles of equal length, the apicals on the yellow. The wing has a not very strongly developed banded pattern : the basal band is reduced to a few odd spots ; stigma and immediately below blackish ; upper cross-vein dark with a faint, narrow cloud on either side ; a short bar across marginal and submarginal cells midway between stigma and end of second vein ; a bar filling end of marginal cell and crossing submarginal ; a broad patch filling ends of submarginal and first

posterior cells ; lower cross-vein dark with a narrow brown margin on either side ; stigma elongate, narrow ; upper cross-vein at middle of discal cell ; lower slightly S-shaped, twice its length from upper ; second vein long ; third rather wavy ; third and fourth somewhat approximated towards ends ; veins yellowish at base of wing, darker outwardly and where touched by pattern ; anal cell rounded at end ; sixth vein not reaching wing margin.

Abdomen. Tergites narrowed but long, 5 about twice as long as 4 ; posterior margin of 4 widened ; base of abdomen black, posterior half of segment 2 yellow ; segments 3, 4, 5, yellow but narrowly black on sides, the black extending inwards broadly on anterior half of segment, but not meeting in middle line (in the Witdraai specimen the tergites 3, 4 and 5 are mainly yellow, the black being reduced to slight brownish submedian spots) ; vestiture black, bristle-like on sides and round end of last segment ; membranes well-developed, dull black ; sternites yellow ; genitalia large and prominent, shining black.

♀. The female, besides being larger than the male, shows certain structural differences, especially in the head. Length of body 4 mm., of wing 2·6 mm. Head (fig. 2), length 1·1 mm., height 1·3 mm., width 1·6 mm. ; frons flatter than in male, one specimen with three inferior orbital bristles on each side ; lunule lemon-yellow, not sunken ; cheeks as wide as third antennal joint, and jowls at widest part opposite lower corner of eye 1·5 times as wide ; haustellum a little longer than base of head, labella somewhat longer still ; middle and hind coxae sometimes brownish, more often yellow ; scutellum black at base and more broadly on sides, only centre and apex yellow. Wing pattern (fig. 2) more strongly developed. The broken basal band is more pronounced ; a broader bar from stigma crosses submarginal and upper cross-vein, sometimes faintly across discal cell, or with only a spot on fifth vein ; a broad bar across marginal and submarginal cells ; a broader bar from end of marginal cell, across submarginal and first posterior cells, narrowly back along fourth vein, then down broadly over lower cross-vein, ending at apex of third posterior cell before reaching wing-margin ; or much broader across first posterior cell and thus broadly confluent with bar over lower cross-vein ; apical spot as in male. In females from Smitsdrift the pattern is very slightly developed, less even than in the male : the bars are almost restricted to dark spots on costa, and the cross-veins hardly darkened at all.

Abdomen normal, segments not narrowed, shining black with fairly broad yellow hind margins to segments 2 to 6, widest on 6. In the Smitsdrift specimens the yellow margins are much wider, covering half to nearly the whole of the segments ; segment 6 about one-third longer than 5 ; vestiture rather sparse black pubescence, bristle-like on margins and round end of last segment. Ovipositor one-third longer than abdomen ; shining black, polished, with sparse black pubescence ; conical, flattened at end. Lateral membranes well-developed but not so much as in male, dull black.

Cape Province : Smitsdrift, Herbert district, 2 ♂♂, 4 ♀♀ (including type ♂), from puparia in flowers of *Geigeria* sp., 23.iii.1928 (*T. J. Naude*). Bechuanaland : Fourteen Streams, 3 ♀♀ (including allotype), from puparia in flowers of *Geigeria passerinoides*, xi.1925 (*S. A. Hunt*) ; Witdraai, 1 ♂, x.1925 (*C. W. Mally*).

Ensina dubia (Walk.).

Walker, Insecta Saundersiana, i, 1856, p. 379 (*Trypeta*).

Loew, Berlin. Ent. Zeit., v, 1861, p. 288, pl. ii, fig. 20 (*Trypeta*).

Bezzi, Ann. S.A. Museum, xix, 1924, p. 551, pl. xv, fig. 103 (*Ensina*).

Munro, Union Dept. Agric. Ent. Memoir v, 1926, p. 30 (as *Ensina magnipalpis*, Bez.).

In view of the comparisons made in the description of the following new species, some notes on *Ensina dubia* (Walk.) seem desirable.

At the present time the specific identity of a series of specimens that I regard as *dubia*, Walk., with Walker's type in the British Museum is not settled to my satisfaction. The specimens seen by me are four from Capetown in the collection of the South African Museum determined by Bezzi as *Ensina dubia* (Walk.) and a large series from East London. I do not think that Bezzi saw more than one or two of the East London specimens, and I have only one specimen he returned to me labelled *Ensina magnipalpis*, Bez., and, based on this determination, I published biological notes on the species under *magnipalpis*, Bez. It was only after this that I saw the Capetown specimens that Bezzi had determined as *dubia* and was at once struck by the similarity to my East London material, the only difference to be noted bei ng that the Capetown specimens are larger than those from East London. Thro ugh the kindness of Sir Guy A. K. Marshall, Director of the Imperial Institute of Entomology, I obtained drawings of the wings of the types of *dubia*, Walk., and of *magnipalpis*, Bez. On comparison of the wings of East London and Capetown material with these

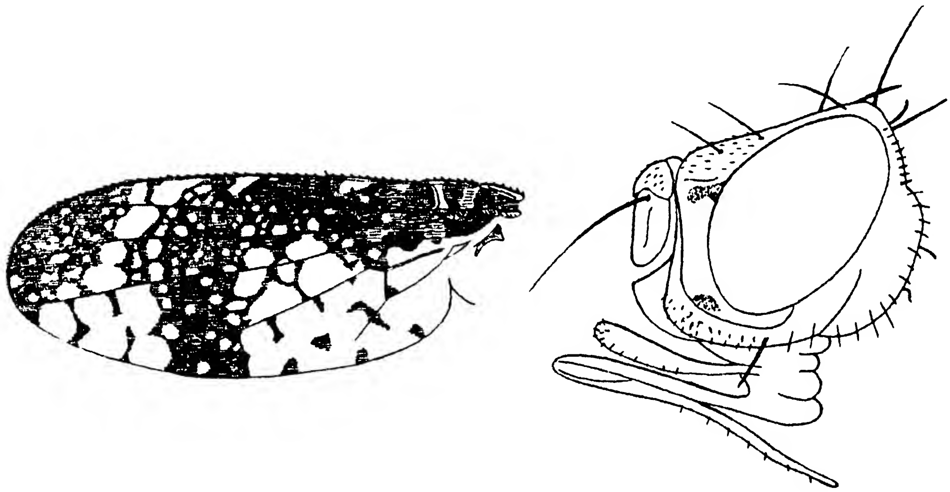

Fig. 3. *Ensina polana*, sp. n., wing and head.

drawings, it would appear that none could be *magnipalpis*, but that, allowing for the slight variations that are always present in the wing-pattern of these flies, they agree very well with the drawing of the wing of *dubia*.

That other characters for the differentiation of the species may be available is to be expected. As regards *magnipalpis*, Bezzi (Bull. Ent. Res., x, p. 261) states that the cheeks are " narrow " ; in the East London and Capetown specimens the cheeks are as wide or nearly as wide as the third antennal joint ; it is unfortunate, however, that the head of the type of *dubia* is missing, hence a careful comparison with a series of specimens would be desirable. Loew's description (1861) is without doubt *dubia*, Walk., but he simply states " Backen von mittlere Breite"—his " Backen " being presumably the jowls and not the cheeks.

Ensina polana, sp. n. (fig. 3).

This species belongs to Bezzi's " *Ensina dubia* " group. In wing pattern it differs from *hieroglyphica*, Bez., and *magnipalpis*, Bez., but approaches very close to *dubia*, Walk. From the last it may be distinguished, however, as the apical

patch consistently only touches the outer tip of the second posterior cell, whereas in *dubia* the apical patch always includes the outer half of this cell. Another difference is that while in *dubia* the length and height of the head are about equal, in *polana* the head is usually one-fifth longer than high, owing to the greater development of the cheeks, jowls and epistome. The species *polana* has been retained in *Ensina* pending a revision of the species placed by Bezzi in this genus.

♂♀. Length of body, male 2·3–2·7 mm., female 4·5–5·0 mm., but two females smaller, 1·9 mm. and 2·4 mm. Wing about as long as body, and three times as long as wide. Head (fig. 3) elongate in profile, from one-fifth to not quite one-third longer, and rather more than one-third wider than high; frons flat, as long as wide at vertex, a little narrowed anteriorly, twice width of one eye, light buffy-brown with parafrontals broadly and thickly white-dusted and a faint white-dusted median stripe that widens slightly to the black ocellar dot, slight white pubescence on anterior end of median stripe and on parafrontals; two inferior and two superior orbital bristles, ocellars well-developed; bristles black except upper superior orbital, outer verticals and post-verticals, which are thick and white; lunule large, semicircular, fawn-colour; antennae normal, honey-yellow, shorter than face, first joint with thickened yellowish bristle; third joint normally broadly rounded at end, sometimes acuminate, probably owing to shrinkage; arista black, except thickened yellow base; face whitish yellow, concave in profile, with projecting epistome; cheeks not quite as wide as third antennal joint, proportions 4 : 5, sometimes as wide, or rather narrower; jowls half as wide again at point opposite lower front corner of eye; polished yellow with brown spot just below base of antennae and a larger brown spot at lower corner of eye; peristomial hairs yellow; eye elongate oval, 1·5 times as long as wide, its long axis forming an angle of 45° with long axis of head; mouth-opening elongate; proboscis linear, geniculate, haustellum a little, and labella one-third longer than base of head; palpi whitish, at times yellowish apically, leaf-like, fairly broad; occiput a little concave above, swollen below, blackish, with thick whitish or yellowish dust especially below, where also clothed with yellowish bristle-like hairs; occipital bristles black with one, two or three white ones among them.

Thorax normal, black in ground-colour; on dorsum with white pubescence and dense dust forming a broad median pale buffy-brown stripe (between dorso-central bristles), the middle anterior two-thirds of this stripe broadly and somewhat densely grey-dusted; sublateral lines, between dorso-centrals and anterior supra-alars, densely grey-dusted, and lateral lines, between anterior supra-alars and notopleural suture, dark buffy-brown; rest of thorax grey-dusted, the black ground-colour giving a blackish tinge especially in certain lights; dorso-central bristles half-way between suture and line of anterior supra-alars; all bristles black, except lower of two mesopleurals that are white and a row of white close-set propleurals. Scutellum flat, grey on disc, buffy-brown with some white pubescence marginally; four bristles of equal length. Front coxae concolorous with pleurae, legs otherwise honey-yellow, except tarsi blackish, and hind femora with blackish tinge or quite black; front femora with outer row of black, and inner row of whitish bristles. Wing normal (fig. 3); a single costal bristle; upper cross-vein beyond middle of discal cell, the lower with a strong outward bend in middle and half its length from upper; end of third vein slightly bent downwards; lower angle of anal cell acute but not produced; pattern a dark fuscous bar along base of costa (with only few hyaline spots), then across wing beyond middle (small hyaline spots more numerous), and an apical oblique patch also with few hyaline spots; the latter extends consistently from a point one-third the distance between the ends of the first and second veins from the end of the latter to a point that just includes the small apex of the second posterior cell; the middle bar and the apical patch are separated by a hyaline bar composed of large, more or less confluent, hyaline spots; the lower half of base of wing is marked similarly with large confluent spots: in the female the hyaline bar is wider and more

complete, the apical patch and the middle bar are narrower and have larger hyaline spots. It may be noted that in fresh specimens the wing pattern is blackish.

Abdomen short, base blackish in male, more buffy-brown in female; rest of abdomen grey or with anterior two-thirds of segments grey and hind third yellowish; on each segment is a pair of large, blackish, submedian spots—faint on the second segment; clothed with yellow pubescence and apically with black bristles; genitalia brownish; ovipositor as long as last four segments, flattened, black at base and apex, reddish yellow in middle.

Type ♂ and ♀, 8 paratype males and 12 paratype females.

Portuguese E. Africa: Polana Beach, Lourenço Marques, 9 ♂♂, 13 ♀♀ (including types), 17 and 19.i.1929, 1 ♀, 18.ix.1928. Natal: Isipingo Beach, 1 ♀, 15.v.1930 (*H. K. Munro*); Doonside, 2 ♂♂, 2 ♀♀, vii.–viii.1930 (*Miss S. Soskin*).

The specimens from Doonside were reared from puparia in the flowers and seeds of *Osteospermum moniliferum* kindly collected for the author by Miss Soskin. The other specimens were all taken on the same species of bush by the author; puparia were found in the flowers at Lourenço Marques, but owing to heavy parasitism and general mortality, no adults were reared.

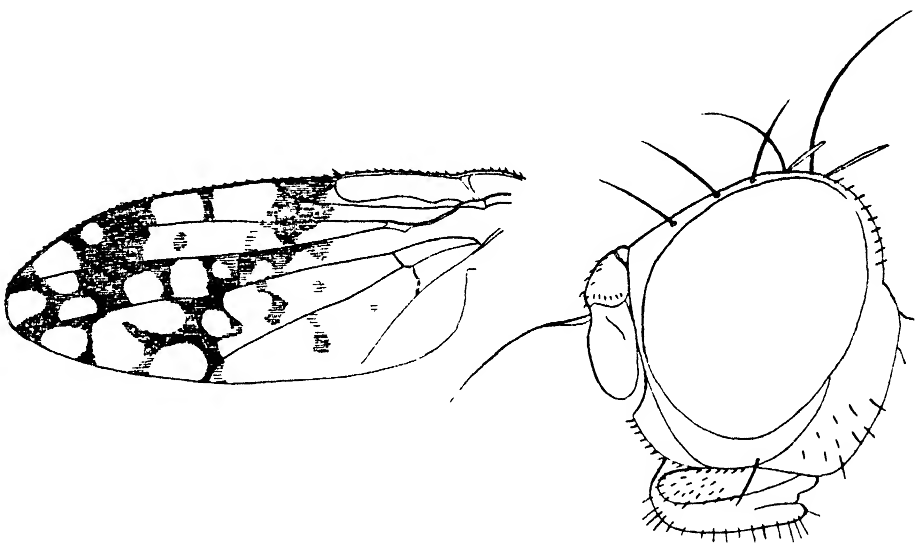

Fig 4 *Tephritis cinerea*, sp n , wing and head.

Tephritis cinerea, sp. n. (fig. 4).

A species that does not fall readily into any genus as recognized by Bezzi, but coming nearest to *Trypanea*. The apical spot and rays are not well developed, and there is moreover a subreticulate pattern over most of the outer two-thirds of the wing. In Hendel's tables it may readily be placed in *Tephritis*, and it does in fact seem to show some relation to the Asiatic species *Tephritis variegata*, Beck., and *T. brachyura*, Lw., to the former in wing pattern in particular.

♂♀. Length of body 2·4 mm., of wing 2·6 mm. Head yellow with blackish occiput, length one-fifth less and width one-third greater than height; frons at vertex nearly twice width of one eye, sides curved inwards anteriorly, as long as width at antennae, which is two-thirds width at vertex, flat, bare, two inferior orbital bristles, lower superior orbital and well-developed ocellars black, upper superior orbital and other bristles yellowish; lunule arcuate; face flat, as wide as long;

cheeks and jowls narrow; genal bristle black, peristomial setae yellow; mouth-opening rounded-oval, epistome not projecting; proboscis short, not geniculate; palpi normal; antennae shorter than face, honey-yellow; arista blackened on apical two-thirds; eyes large, rounded; occiput largely black centrally, concave above, swollen below and with yellow hairs; occipital bristles yellowish.

Thorax normal, bristles brownish black except posterior notopleural, row of propleurals and pteropleurals yellow; dorso-centrals on suture; ground-colour black; humeri, notopleural stripe and base of wings yellowish; clothed with thick grey dust (mostly denuded) and white pubescence; scutellum black with grey dust, two long basal bristles and two short, smaller, apicals. Halteres yellow. Legs honey-yellow. Wings (fig. 4): upper cross-vein at outer third of discal cell; lower slightly curved outwardly, one-tenth longer than its distance from upper; ends of third and fourth veins parallel; lower angle of anal cell pointed; sixth vein not reaching wing margin; a single costal bristle; a subreticulate pattern on outer two-thirds of wing; stigma black, apical spot and rays not well-developed.

Abdomen normal, short, black, more or less yellow at base, especially on venter, clothed with grey dust and white pubescence. Genitalia black. Ovipositor shining black, with some white pubescence, as long as last two segments, which are of equal length.

Cape Province: Lady Grey, 2 ♂♂, 3 ♀♀ (including types), 6.i.1925 (*R. I. Nel*).

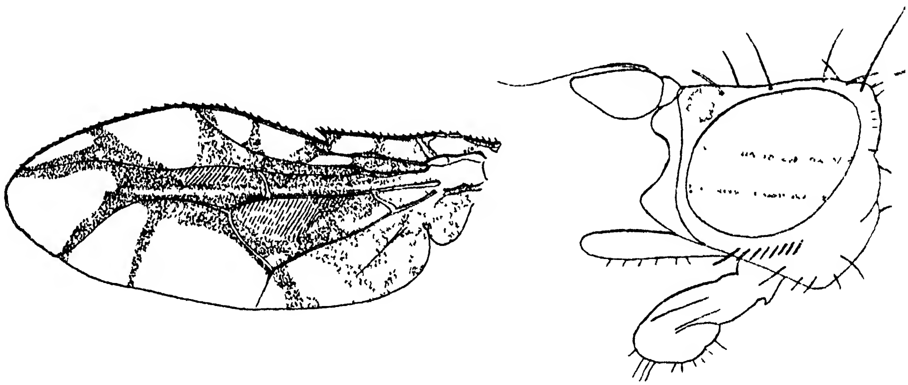

Fig. 5. *Cyanodesmops ornithomorpha*, gen. et sp. n., wing and head

Cyanodesmops, gen. n.

Allied to *Schistopterum*, Beck., especially in wing venation and pattern, but differing in shape and chaetotaxy of head.

Head as long as high; epistome projecting; cheeks narrow; face with carina at top; eye rounded-oval; proboscis short, not geniculate; two superior orbital, three inferior orbital and small ocellar bristles. Thorax normal; dorso-centrals before suture; scutellum with four bristles, the basals long, the apicals very short. Wing with deep cleft before small stigma; fourth vein strongly curved downwards; anterior cross-vein beyond middle of discal cell, anal cell indistinct; ovipositor robust, as long as rest of abdomen; in female sixth segment as long as fifth.

Genotype the following new species.

Cyanodesmops ornithomorpha, sp. n. (fig. 5).

A small blackish species allied to *Schistopterum moebiusi*, Beck., especially in wing characters, but differing markedly in the longer head and in the presence of two superior orbital, three inferior orbital and small ocellar bristles.

♂♀. Length of body and wing in ♂ 1·5 mm., body in ♀ 2·1 mm., wing 1·7 mm.

Head as long as high and about one-third wider ; frons as long as width at vertex, narrowed anteriorly, flat, bare, in profile forming a projecting right angle with face, dull brownish to brownish black, with broad white pollinose parafrontals ; vertical triangle large, straight-sided, equilateral, shining black ; lunule well defined, arcuate, black ; two superior orbital bristles, the lower long, black and thin, the upper flattened and white ; three inferior orbitals, the two upper black and thin, the lowest white and shorter, the middle more inward than the other two ; inner verticals long, black and thin, the outer short, flat and white ; post-verticals short, white ; ocellars short, black ; occipitals short, black, with usually one or two white on either side ; antennae porrect, large, longer than face, brownish black, third joint broad at base tapering to a fairly acute point ; arista white, with brownish thickened base ; face short, deeply concave in profile, having a strong median carina above below antennae and epistome strongly projecting, shining black, with a white pollinose band across lower half ; cheeks narrow, jowls wider, black ; occiput hollowed above, swollen below, black, broadly pollinose on lower part, pollen extending to below eyes, with row of thickened yellow bristles to genal angle, and a few black bristles on occiput below ; oral opening rounded-oval ; proboscis normal, short, not geniculate, yellow, labella large ; palpi elongate, projecting considerably beyond epistome, yellow on basal third, black on apical two-thirds ; eyes rounded-oval ; in life dark reddish brown, with a narrow, pale, shining blue bar horizontally across slightly above middle, parallel to it a similar wider bar across lower half of eye, widening slightly in front, and top quarter of eye also pale bluish.

Thorax rather dull brownish-black ; on dorsum are four faint longitudinal stripes of grey dust, two submedian and two lateral, the submedian and lateral on either side appearing as one broad stripe in certain lights ; on the grey stripes is a little deciduous white pubescence. On pleura is a grey bar from front coxae to mesopleural suture. Chaetotaxy normal : two humerals, the outer long black, the inner short, white ; pteropleural long, white, flattened ; other bristles all slender, brownish black ; one mesopleural ; dorso-centrals before suture. Scutellum concolorous with thorax, rather swollen ; two lateral, long bristles brownish black, two apicals very short, white. Halteres brownish black. Legs brownish black (except front tibiae on distal three-quarters, middle pair one-quarter, and hind apically, yellow) ; all tarsi yellow (except last two joints, brown) ; front femora with black bristle near distal end, and a white bristle near middle on inner posterior surface ; vestiture of legs black. Wings very like *Schistopterum moebiusi*, Beck., in venation and pattern (fig. 5). The costal cleft and projection, which bears two bristles, well defined but not quite so large as in *S. moebiusi* ; stigma small ; second vein wavy and meeting costa at acute angle, not so rounded and recurved as in *S. moebiusi* ; third vein long and wavy, meeting margin a little above apex of wing ; fourth vein strongly curved downwards about half-way between upper cross-vein and apex of wing ; fifth vein short ; sixth vein barely reaching wing margin ; anterior cross-vein beyond middle of discal cell ; lower long, in length nearly twice its distance from upper ; discal and second posterior cells large ; anal cell indistinct. Pattern as in fig. 5.* It is characterised by a broad brownish-black bar along the middle of the wing giving off rays to wing margin ; at base of wing the pattern is more or less broken and somewhat reticulate ; two dark reddish-brown bullae are present, one at base of first posterior cell, the other in the outer half of discal cell. The pattern is formed mainly by a brown coloration of the wing membrane on which are very many, minute, closely placed groups of about ten extremely minute black microtrichiae and one normal-sized microtrichia ; this condition is found on the middle portion and on all the outer rays, except the bullae which are destitute of microtrichiae ; variations in

* In the figure the pattern has been indicated much lighter than it actually is, in order to show the venation : the bullae are cross-hatched.

the intensity of the pattern are caused (1) by the absence of brown in the membrane, *i.e.*, along the longitudinal wing-fold along the first basal and first posterior cells and the lower portion of the discal cell; (2) by single, black, normal microtrichiae—no groups—on brown coloration, *i.e.*, in lower inner and outer corners of discal cell, much of wing base, spots in anal cell and on alula; (3) single black microtrichiae on hyaline membrane, *i.e.*, spots in wing-base and most of pattern in anal angle and on alula. Costa yellow hyaline, but brownish black where touched by rays; veins brownish, except small hyaline sections of first and second veins and pale yellowish upper and lower cross-veins.

Abdomen short and wider than thorax; shining black with black pubescence; hind margins of segments 2, 3 and 4 with one or two deciduous white hairs on either side of middle line; last segment in male large, as long as 3 and 4 together, highly polished black, with a few short black bristles on hind margin. Venter dull black. Genitalia large, shining black. In female, segments normal, 6 as long as 5. Ovipositor robust, shining black, with black pubescence, as long as abdomen, gaiter-shaped, width at base nearly half length, apex slightly flattened; sixth and sometimes fifth segments with very narrow brownish hind margins.

TRANSVAAL: Pretoria, 14 ♂♂, 7 ♀♀ (including types), xi.1928, 6 ♂♂, 7 ♀♀, xi.1929 (*H. K. Munro*).

The flies were only found on the flowers of *Epaltes alata*, Steetz. (Compositae), on which they were fairly numerous. It is presumed that the larvae live in the flowers, but although many were examined, only a couple of very young Trypetid larvae, new to the author, were found. The flies are remarkably pretty and have a very bird-like appearance when resting on the flowers and twigs.

NOTES ON AFRICAN CHALCIDOIDEA.

By CH. FERRIÈRE, D.Sc.,

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Fam. EURYTOMIDAE.

Eurytoma verbena, sp. n.

♀♂. Black; abdomen sometimes a little reddish on the sides. Antennae dark brown; pedicel slightly yellow below. Wings whitish, with the veins very clear yellow. Legs with coxae and femora black, the latter sometimes a little reddish; tibiae red in the middle, often mixed with black, especially at the hind tibiae; knees, base and tip of tibiae, and the tarsi whitish.

♀. Head rugulose, face covered with white ciliae, with a carina between the base of antennae and the clypeus, and weaker striae diverging from the mouth. Antennal furrow rather deep, bordered by a carina and reaching almost to the median ocellus. Cheeks as long as half the length of the eyes, finely rugulose. Antennae inserted in the middle of the face; scape short, reaching very little beyond the top of the antennal furrow; pedicel not longer than broad; annelli very small; funicle joints longer than broad, the 1st almost twice, the 2nd about 1·5 times longer than broad, the following gradually shorter.

Thorax more strongly sculptured than the head, reticulate. Scutellum protruding a little above the postscutellum, which is hidden, and the propodeon; this latter, seen from the side, has the posterior margin almost vertical. Mesopleurae finely punctate, with some short horizontal striae; episternum transversely striate, but the striae not reaching to the hind margin, along which it is punctate, like the mesopleurae. Propodeon rugulose reticulate on the sides, with irregular longitudinal striae; the posterior concave area of the propodeon a little broader than long and punctate. Wings with a short marginal vein, little longer than the stigmal vein and a little shorter than the postmarginal vein. Legs normal, coxae punctate, without teeth or plates.

Abdomen as long as head and thorax united, compressed from the sides; segments finely shagreened; petiole short, transverse, segment 5, seen from the sides, longer than segments 2 to 4 together, the remainder short. Pygidium protruding, the sheaths of the ovipositor exceeding it slightly.

♂. Similar to the female, smaller. Antennae elongate, the funicle joints long and nodulose, each with two circles of white ciliae; each joint is separated from the following by a narrow petiole, about twice as long as broad; between the 5th joint and the club the petiole is shorter but quite as thin; club with 2 joints.

Length: ♀, 2·8–3·0 mm.; ♂, 2·3–2·5 mm.

ITALIAN SOMALILAND: 2 ♀♀, 2 ♂♂, viii.1926 (*Prof. G. Paoli*).

Type deposited in the British Museum.

Host. Bred with larvae of *Platyedra gossypiella*, Saund.

One other large female of 4·5 mm. in length, obtained from the same breeding place, x.1926, is morphologically quite similar to this species, from which it differs only through the size.

This species is closely related to our *Eurytoma braconidis* from East Africa, a hyperparasite of *Platyedra*. It may be distinguished, however, by the antennae

having more elongate funicle joints, the shorter marginal vein, the posterior area of the propodeon more punctate, the episterna with less complete transverse striae, and the finely striate abdomen with the 5th segment longer than the others.

Eurytoma syleptae, sp. n.

♀♂. Body black. Antennae black, with the distal end of the scape and the pedicel more or less brownish. Wings with clear yellowish-brown veins. Legs with coxae, outer base of anterior femora, middle and hind femora (except apex), and posterior tibiae, mostly black; anterior trochanters, end of femora, anterior and middle tibiae and both ends of posterior tibiae, orange-yellow; tarsi whitish.

♀. Head reticulated above, the face smooth, with converging striae to the mouth, the median carina short and not well marked; on the sides two stronger carinae unite the sides of the antennal furrow to the clypeus, forming an elongate triangular area in the middle of the face. Antennal furrow short and deep. Cheeks as long as two-thirds the length of the eyes. Antennae thin, scape narrow, reaching to the anterior ocellus; pedicel short, rounded; annelli very small, almost inconspicuous; 1st funicle joint elongate, about twice as long as broad, the remainder a little shorter, but each narrow and distinctly longer than broad; club almost as long as the two preceding joints united.

Thorax strongly reticulate. Scutellum short, rounded. Propodeon roughly reticulate on the sides, the posterior area concave, punctate, with a median row of short transverse carinae. Mesopleurae punctate in the middle, reticulate near the mesonotum and irregularly transversely striate on the episterna. Wings with the marginal vein a little longer than the stigmal and postmarginal veins; the two latter of about the same length. Legs with coxae, especially the posterior, punctate.

Abdomen rather strongly compressed from the sides, as long as head and thorax together; segments quite smooth, the 5th only finely punctate on the ventral sides; petiole narrow, a little longer than broad; segments 2 to 4 short, 5 large, longer than the preceding united; 6 almost hidden by 5, pygidium protruding, very little exceeded by the sheaths of the ovipositor.

♂. Similar to the female. Antennae elongate, scape short and a little thickened; pedicel small and rounded; the funicle joints elongate, enlarged in the middle, separated by a short petiole and each with two circles of white ciliae, which are as long as the joint; between the 5th joint and the club the petiole is as narrow as between the joints; club with 2 joints. Abdomen small, rounded, the petiole distinctly longer than the hind coxae.

Length: ♀, 2–2·4 mm.; ♂, 1·8–2·1 mm. One very small ♀ is only 1·6 mm. long, and one ♂ is 1·5 mm. long.

SIERRA LEONE: Njala, 8 ♀♀, 5 ♂♂, 19.xi.1928 (*E. Hargreaves*).

Type in the British Museum.

Host. Ex larva of *Sylepta derogata*, F.

With these two new species, we have now three African *Eurytoma* parasites or hyperparasites of cotton worms, which at first glance are very much alike. They may be distinguished by the following key:—

1. Antennae with all the funicle joints short, not or little longer than broad. Posterior area of propodeon as long as broad, finely punctate, shining. Abdominal segments of about equal length, quite smooth above. *E. braconidis*, Ferr.

   Antennae with at least the first four funicle joints distinctly longer than broad. Posterior area of propodeon more strongly punctate or rugulose. Abdomen with the 5th segment longer than the others 2

2. Antennae strong, the last two funicle joints little longer than broad. Stigmal vein as long as the marginal vein. Posterior area of propodeon punctate, sometimes irregularly rugulose in the middle. Abdomen finely punctate above ... ... *E. verbena*, sp. n.

   Antennae narrower, the last two funicle joints about twice as long as broad. Stigmal vein shorter than the marginal vein. Posterior area of propodeon punctate, with a row of transverse striae along the middle. Abdomen quite smooth ... ... *E. syleptae*, sp. n.

Fam. ENCYRTIDAE.

Psyllaephagus phytolymae, sp. n. (fig. 1).

♀. Head and thorax shining metallic green, slightly golden-reddish on the sides of the mesonotum. Mesopleurae red-purple. Propodeon and abdomen aeneous, with some greenish or reddish reflections. Antennae brown, the end of scape and pedicel, the last funicle joints and the club more yellow. Palpi, tegulae and legs yellow, the coxae and the basal two-thirds of hind femora black.

Head finely granulose; vertex broad, with the lateral ocelli nearer to the eye margin than their own breadth, forming with the anterior ocellus a low triangle. Cheeks distinctly shorter than the diameter of an eye. Mandibles with 4 teeth, the

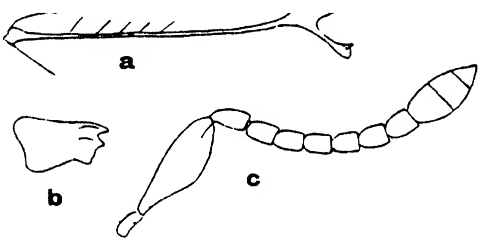

Fig. 1. *Psyllaephagus phytolymae*, sp. n., female: *a*, venation; *b*, mandible; *c*, antenna.

two inferior teeth very small and truncate. Antennae inserted at the level of the base of the eyes; radicula thin, about twice as long as broad; scape large, much broadened below; pedicel twice as long as its apical breadth; 1st funicle joint as long as the pedicel, the following joints of about the same length as the 1st, but gradually broader so that the last is little longer than broad; club with 3 joints, broader than the funicle, about as long as the two preceding joints together.

Thorax shagreened; the mesonotum and scutellum covered with white ciliae, Tegulae large; axillae triangular, elongate, meeting in the middle; propodeon very short. Wings large, hyaline; marginal vein short, punctiform; postmarginal vein also short, half as long as the stigmal vein, which is thin and elongate.

Abdomen triangular, a little longer than the thorax; ovipositor slightly protruding.

Length: 2 mm.

NIGERIA: Onitsha, 1 ♀, 17.ix.1928 (*D. R. Rosevear*).

Type in the British Museum.

Host: a Psyllid, *Phytolyma lata*, Scott (Iroko gall bug), on *Chlorophora excelsa*, Welw.

The biology and morphology of this Psyllid has been studied by J. Vosseler (Zeitsch. wiss. Insektenbiol., ii, 1906, pp. 276–285, 305–316). He observed also the Encyrtid

parasite and, without naming it, gives a short description and a drawing of it. From his description we translate the following extract concerning the characters of the male, which we have not seen :

"The male (fig. 18) seems on the average a little larger than the female, its abdomen less elongate and strongly triangularly pointed. The antennae show distinct sexual dimorphism ; they are, in the male, thin, filiform, in the female shorter, broader and somewhat thickened at the end. The flagellum joints of the male antennae are long oval, covered with long erect black hairs. Both sexes have the 1st small joint [radicula] about twice as long as broad, the 2nd [scape] about 4 times as long as broad, strongly inflated behind the middle, the flagellum with 8 joints [pedicel, 6-jointed funicle, 1-jointed club, as seen by the author], its 1st joint [pedicel] in the male very small, rounded, black." All the parts in brackets have been added to render the description more comprehensible. A short description of the larva and pupa is also given, as well as some biological data.

This species is a typical *Psyllaephagus*, closely related to *P. pachypsyllae*, How., from U.S.A., and to *P. euphyllurae*, Silv., from Europe. It is, however, well characterised by the enlarged scape and the more elongate funicle joints, which are not distinctly shorter than the pedicel. This is the first species of the genus recorded from Africa.

Fam. PTEROMALIDAE.

Neocatolaccus sphenopterae, sp. n.

♀♂. Head and thorax dark green, almost black ; abdomen aeneous ; propodeon and 1st segment of abdomen more shining green. Antennae, tegulae, wing veins and legs, brown ; scape and pedicel, tibiae and tarsi, except middle of median tibiae and base of hind tibiae, yellowish ; tibiae and tarsi quite white in the male ; all coxae concolorous with the thorax.

♀. Head seen from in front rounded, punctate, the striae diverging from the mouth very fine, not easily seen. Face a little swollen. Cheeks large, almost as broad as the eyes. Both mandibles with 4 teeth. Seen from above, the head is transverse, narrowed behind the eyes, occiput not margined ; vertex narrow, the lateral ocelli closer to the median ocellus than to the eye margin. Antennae inserted in the middle of the face, above the level of the base of the eyes ; scape thin, slightly curved, reaching to the median ocellus ; pedicel narrow, twice as long as broad ; the 3 annelli transverse, the 3rd a little larger than the two others ; 1st funicle joint large, broader and longer than the pedicel, the 4 following joints equal in length, shorter than the 1st, about 1·5 times as long as broad ; club oval, with 3 joints, shorter than the two preceding joints together.

Thorax rugulose-punctate, covered with sparse short white ciliae ; pronotum very short ; mesonotum broader than long, flat above, with the parapsidal furrows only to the middle ; scutellum as long as its posterior breadth, almost flat ; propodeon very short, without nucha, with a median carina and lateral furrows ; spiracles rather large, oval. Wings large, without discal ciliation at the base ; marginal vein half as long as the submarginal ; postmarginal vein narrower and shorter than the marginal ; stigmal vein not much shorter than the postmarginal, about as long as two-thirds the length of the marginal, slightly curved. Legs strong, front and hind femora somewhat thickened, the hind tibiae longer than the femora, with one strong spur.

Abdomen oval, much pointed behind, longer than the thorax ; segments 2 to 4 short, transverse, 5 as long as its anterior breadth, strongly narrowed behind. Ovipositor slightly protruding.

♂ quite similar, but the antennae narrower and with only 2 annelli, the 6 funicle joints longer than broad. Abdomen shorter than the thorax.

Length : ♀ 2·7–3·3 mm. ; ♂ 2·6 mm.

ANGLO-EGYPTIAN SUDAN : Barakat, 2 ♀♀, 5.xii.1924 ; Wad Medani, 5 ♀♀, 23.i.1925, 1 ♂, 20.xii.1924 (*H. B. Johnston*).

Type in the British Museum.

Host. Sphenoptera gossypii, Cotes.

Owing to the 3 annelli in the antennae of the female, its short propodeon without a nucha, and its elongate abdomen, this species belongs to the genus *Neocatolaccus*, Ashm., as defined by Ashmead and Kurdjumov. The genus *Aplastomorpha*, Crawf., is also very similar, but the cosmopolitan *A. calandrae*, How., is distinguished by its broader vertex, the marginal vein as long as the postmarginal, its shorter abdomen, and smaller size. Our African species is more related to the American *N. tylodermae*, Ashm., which is also a parasite of beetles.

Fam. ELASMIDAE.

Elasmus leucopterae, sp. n.

♀. Body black with bluish-green metallic shine. Postscutellum quite white. Abdomen more aeneous black, with the 1st segment greenish at the base and reddish on its second half, and with the ventral side red on the basal two-thirds. Antennae brown, scape and pedicel yellow. Legs pale yellow with black ciliae, the hind coxae greenish black at the base, and the median and hind femora with brown lines above and below ; these lines are a little broader near the end of the hind femora.

Head narrow, vertex with sparse punctation. Antennae inserted at the base of the face, scape very short, distinctly shorter than the two following joints united ; pedicel small, 1·5 times as long as broad ; 1st funicle joint elongate, longer than the pedicel, almost as long as the scape ; 2nd and 3rd joints longer than broad, but shorter than the 1st ; club with 3 joints, as long as the two preceding joints together.

Mesonotum finely shagreened, about as long as its hind breadth ; scutellum and propodeon almost smooth ; postscutellum large, triangular. Wings hyaline, reaching to the tip of the abdomen. Legs shining, with the hind femora very finely striate ; the hind tibiae with the hairs arranged in regular lozenges.

Abdomen narrow, a little longer than head and thorax together, pointed at apex ; 1st segment a little shorter than its posterior breadth ; each following segment transverse, except the 6th which is as long as broad in the middle, and the 7th triangular. Ovipositor slightly protruding.

Length : ♀ 1·75 mm.

TANGANYIKA : Morogoro, 1 ♀, vii.1929 (*A. H. Ritchie*).

Type in the British Museum.

Host. Leucoptera coffeella, Guér.

This species is very distinct from all the other African species. It is very similar to the Malayan *E. corbetti*, Ferr., from which it differs by its smaller size, its body and wings less elongate, with no abdominal segment longer than broad, by its reddish band on the 1st segment of the abdomen, and the base of the hind coxae less broadly black.

Elasmus flaviceps, sp. n.

♀. Body dark green, with bluish reflections on mesonotum, propodeon and base of abdomen. Head yellow, stemmaticum and occiput blackish ; the upper part of the face sometimes brownish. Antennae brown, the scape yellow. Yellow are also : two spots near the tegulae, the base of the wings, a band along the tip of the scutellum, the postscutellum and the legs, except the basal half of the hind coxae and

thin black lines on the upper part of all femora. Abdomen aeneous, the ventral side reddish at the base.

Head transverse, the face sunken after death, vertex with the punctation sparse and weak. Antennae inserted at the base of the face; scape short, about half as long as the distance between the base of the antennae and the ocelli, as long as the two following joints together; pedicel small, 1·5 times as long as broad; 1st funicle joint elongate, longer than the pedicel, more than twice as long as broad; 2nd and 3rd joints a little shorter, but each still about twice as long as broad; club with 3 joints, as long as the two preceding joints united.

Mesonotum almost smooth, with the usual ciliation, a little broader than long; scutellum finely shagreened; postscutellum triangular, much pointed behind; propodeon smooth. Wings hyaline, reaching to the tip of the abdomen. Legs shining, smooth, the striation very weak, visible only at the base of the hind coxae; hind tibiae with the black hairs arranged in lozenges.

Abdomen narrower than the thorax and not much longer; 1st segment longer than broad, the following short, transverse, except the 6th which is as long as its basal breadth, and the 7th forming a regular triangle. Ovipositor slightly protruding.

Length: 1·4–1·7 mm.

ANGLO-EGYPTIAN SUDAN: Talodi, 4 ♀♀, 12.x.29 (*F. G. S. Whitfield*).

Type in the British Museum.

Host. Hyperparasite of *Sylepta derogata*, F.

This very peculiar species, with its yellow head and the yellow band at the end of the scutellum, would run in our key of African and Asiatic species (Bull. Ent. Res. xx, 1929, p. 422) to No. 19. It differs, however, much from *E. ceylonicus*, Ferr., which has a dark head and mesonotum, black hind coxae and a more reddish abdomen; and from *E. eximius*, Masi, which has the cheeks, mouth, side of pronotum, almost all the scutellum, and the greater part of the abdomen reddish yellow.

Elasmus masii, Ferr. var. **natalensis,** nov.

Quite similar to the type of this species, from the Seychelles, in size, morphology and dark coloration. The only difference is in the coloration of the hind legs, which in the series from South Africa have the tibiae as dark as the femora, except the short white base, and not brownish. The funicle joints are also on the average somewhat shorter, being about twice as long as broad; but this latter character is liable to vary and is not so constant as the darkness of the hind tibiae.

NATAL: Zululand, Ntambanana, 8 ♀♀, iv.1930 (*J. S. Taylor*).

Host. Ex pupa of *Apanteles diparopsidis*, Lyle, parasite of *Diparopsis castanea*, Hmps., on cotton.

As we have been told by Dr. Hugh Scott, who collected the Seychelles insects, most of the small Chalcids have been found in the cultivated plains, and some of them are already known to occur also in Africa or to be related to African species; whereas the greater part of the insects collected in the mountain forests have more relations with the Oriental fauna.

Fam. EULOPHIDAE.
Subfam. ENTEDONINAE.

Euderus gossypii, sp. n. (fig. 2).

♀♂. Body very dark green, almost black, sometimes more or less bluish, or with a purple shine on the vertex. Antennae brown, scape and pedicel dark green, like the body. Legs dark, with greenish reflections on coxae and femora, tibiae more brownish; knees shortly, tip of tibiae and tarsi, whitish. Wings hyaline.

♀. Head transverse, narrowed behind the eyes ; vertex broad, ocelli almost in a line, the lateral nearer to the eye margin than their own diameter. From in front, the head is rounded, cheeks almost as long as half the length of the eyes. Antennae inserted a little below the lower level of the eyes ; scape strong, not quite reaching to the median ocellus ; pedicel narrower, as long as one-third of the scape ; annelli very short, transverse ; 1st funicle joint a little shorter than the pedicel but broader, longer than broad ; the following joints rounded, the 2nd as long as broad, the 3rd and 4th broader than long ; club with 3 joints, not broader than the funicle, as long as the two preceding joints together, the 3rd joint ending in a short spine.

Thorax shagreened, dull ; parapsidal furrows entire ; scutellum almost as long as broad. Propodeon very short in the middle, with a median carina ; spiracles rounded. Wings with the marginal vein as long as the submarginal vein, slightly thicker at the base ; stigmal vein very short, the club almost sessile ; postmarginal vein a little longer than the stigmal vein. Discal ciliation short and rather dense on the apical half of the wing, some of these ciliae forming regular lines, three of which diverge from the stigmal knob, one runs from the middle to the tip of the wing, and one is lower down parallel to the inferior margin of the wing. Under the marginal vein is a short row of longer ciliae.

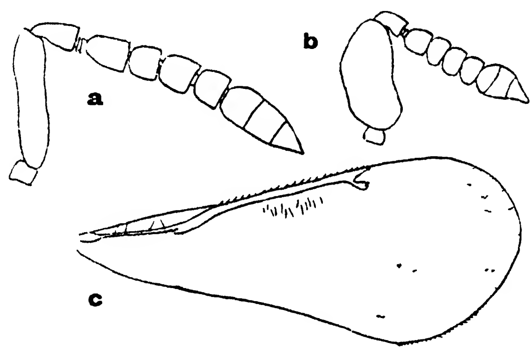

Fig 2 *Euderus gossypii*, sp n *a*, female, and *b*, male, antenna , *c*, wing

Abdomen elongate, longer than head and thorax united, the segments of about equal length. Ovipositor protruding, as long as about one-fifth of the abdomen.

♂. Similar but smaller ; abdomen shorter. The main difference lies in the form of the antennae, in which the scape is much thickened, a little impressed in the middle, in the form of a bean, and not quite two and a half times as long as broad ; it is as long as the pedicel with 4 funicle joints united ; these joints are very small, the pedicel a little longer than broad, the funicle joints transverse, except the 1st which is rounded and as long as broad ; club short and broad, not much longer than the two preceding joints together.

Length : ♀ 1·7–2·3 mm. ; ♂ 1·6–1·8 mm.

ANGLO-EGYPTIAN SUDAN : Wad Medani, 62 ♀♀, 5 ♂♂ (*H. B. Johnston*).

Type in the British Museum.

Host. Larva of *Sphenoptera gossypii*, Cotes, in cotton stems. The dates of breeding are : 23.vi.23, 9.xii.23, 21.i.24, 16.xi.24, 11 xii.24, 23.i.25, 27.vii.25, 7.xi.25, which seems to show that there are two generations in the year, one in November-January and one in June-July.

One female of the same species has been received also from INDIA, Punjab, Lyallpur, 24.i.28 (*U. Bahadur*) as a parasite of *Sphenoptera gossypii.*

This species would run in the genus *Secodella*, Gir., near *S. cushmani*, Crawf., and *S. subopaca*, Gahan, from the U.S.A. This latter species, a parasite of *Rhyacionia frustrana*, Comst., has also the enlarged scape in the male, but seems to differ by the more strongly punctate thorax, by the sparser and weaker discal ciliation of the wing and by the shorter ovipositor.

It is also related to *Allomphale cavasolae*, Silv., a parasite of *Dacus oleae* in Erytrea, but that species has the funicle joints longer, the scape of the male normal and the discal ciliation much sparser between the rows of ciliae. We have seen the type of *Allomphale aemula*, Masi, from the Seychelles, which, although more like *A. cavasolae*, Silv., is congeneric with our species.

We have no doubts that *E. gossypii* is also congeneric with *Euderus amphis*, Walk., the type of the genus *Euderus*, Hal., which is in the British Museum, and we come to the conclusion again that *Secodella*, Girault, as well as *Allomphale*, Silvestri, are synonyms of *Euderus*, Haliday.

Dasyscapus parvipennis, Gahan.

Dasyscapus parvipennis, Gahan, Proc. U.S. Nat. Mus., lxxi, no. 2676, 1927, p. 26, pl. i, fig. 1.

This curious small species, with narrow wings and swollen scapes in the male, was first found in Java as a parasite or hyperparasite of *Thrips tabaci*. Several

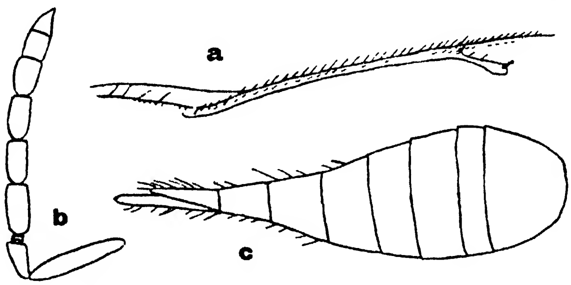

Fig. 3. *Aprostocetus roseveari*, sp. n., female: *a*, venation; *b*, antenna; *c*, abdomen.

specimens, ♂♂ and ♀♀, have been sent to the Imperial Institute of Entomology from West Africa, Gold Coast, by Mr. G. S. Cotterell, where they were reared from *Heliothrips rubrocinctus*.

After comparison with the description and figure of Gahan, as well as with co-types in the British Museum, we have not been able to find any difference between the African and Javanese specimens, so that they belong without doubt to the same species. It is curious to find this species in two such remote parts as Java and the Gold Coast. But it must be remembered that the parasites of Thrips are still very little known and that they may be distributed all over the world with the noxious THRIPIDAE. Another Thrips parasite, *Thripoctenus brui*, Vuillet, observed in Java together with *Dasyscapus*, was first found in Europe as a parasite of *Frankliniella robusta* on peas. In Java *D. parvipennis*, Gahan, is considered as a probable hyperparasite on *Thripoctenus*, but in West Africa no other parasite seems to have been reared with it from *Heliothrips*.

Subfam. TETRASTICHINAE.

Aprostocetus roseveari, sp. n. (fig. 3).

♀. Head orange-yellow, with a spot on the stemmaticum and the occiput black. Thorax and abdomen black, with the sides of the scutellum more or less, the postscutellum, the tegulae, the basal two-thirds of the 1st abdominal segment,

and the 7th segment entirely, reddish yellow. Antennae brown, scape and pedicel yellowish. Legs pale orange-yellow, only the coxae black. Wing veins pale yellow.

Head small, not broader than the thorax; vertex very narrow, the two lateral ocelli on the vertex, the distance between them twice as long as between one ocellus and the eye margin; the median ocellus on the front. Seen from in front the head is triangular, the cheeks almost as long as the eyes. Antennae inserted in the middle of the face; scape narrow, reaching just beyond the median ocellus; pedicel elongate; annellus small, transverse; funicle with 3 joints, the 1st elongate, longer than the pedicel, the following a little shorter than the 1st; club with 3 joints, as long as two preceding joints together.

Thorax shagreened, dull; pronotum transverse; mesonotum elongate, with deep parapsidal furrows; instead of the median longitudinal furrow, there is a faint smooth line along the middle; scutellum as long as broad, with well marked longitudinal furrows. Propodeon very short, almost reduced to nothing in the middle, enlarged at the sides, with large short oval spiracles; mesopleurae smooth. Wings large, hyaline, reaching to the 6th abdominal segment; marginal vein longer than the submarginal, stigmal vein narrow with a very small knob. Legs slender, posterior coxae strong, shagreened like the thorax.

Abdomen narrow, 3 times as long as the thorax; all the segments, except the short 2nd, of about equal length, the 1st and 5th as long as broad, the 3rd and 4th broader than long, the 6th strongly narrowed behind, longer than its middle breadth, the 7th and specially the 8th narrow and elongate; ovipositor protruding, not quite as long as the 8th segment.

Length: 2·2–3 mm.

NIGERIA: Onitsha, 3 ♀♀, 17.ix.28 (type), 21.ix.28 (*D. R. Rosevear*).

Type in the British Museum.

Host: a Psyllid, *Phytolyma lata*, Scott (Iroko gall bug), on *Chlorophora excelsa*, Welw. Bred with the Encyrtid, *Psyllaephagus phytolymae*, described above.

This species is remarkable by its long abdomen, with elongate posterior segments. By this character it is related to the genus *Hyperteles*, Först., but has quite different antennae. In the key given by Girault of the Australian genera (Mem. Queensl. Mus. ii, 1913, p. 249), it runs down to *Asyntomosphyrum*, Girault, if we take the mesonotum to be without median sulcus, or to *Aprostocetus*, Westw., if we consider the smooth longitudinal line on the mesonotum as a very weak sulcus. Although *Asyntomosphyrum* has also a " pointed conic-ovate abdomen," and the ovipositor may not be considered here as being exserted so much as in many *Aprostocetus*, it is in this older genus that our species is best placed, owing to the form of the antennae and body. This is the first species of this genus from Africa.

NOTES ON THE BIONOMICS OF *ANOPHELES ELUTUS*, EDW. (DIPT., CULIC.).

By G. MER,

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Seasonal Variation in the Fertility of Anopheles elutus Females.

The seasonal distribution of *Anopheles elutus* in Palestine is very curious. Kligler[2] has shown that the density curve of *A. elutus* presents two peaks : one in May-June, and the other in October-November, separated by a drop to almost complete disappearance of the adults in August-September. The breeding goes on all the summer, beginning in April and ending in October. These results have repeatedly been confirmed. The accompanying density curve (fig. 1), based on bi-weekly estimations of adult *A. elutus* found in fixed catching stations in a Bedouin village on the shore of a large swamp, illustrates this phenomenon. This curve shows the same two peaks and the drop in the middle of the summer. During the last half of November, December and January, the number remains constant and is followed by a second drop in February-March. During this period only overwintering females are present, and they gradually disappear.

The cause of the drop beginning with June is not clearly understood. It may either be due to diminished production of new mosquitos or to increased destruction of old adults, or to both. Our attention was, therefore, directed to the solution of this obscure problem.

The first step was to ascertain whether the fertility of the females remained the same throughout the year. *A. elutus* females caught in nature with more or less developed ovaries were separated into individual cages. The number of eggs in each batch was noted, a monthly average per laying female was calculated, and a curve based on 378 layings constructed. This curve (fig. 1) demonstrates a number of facts :—

(1) The fertility of female *A. elutus* is not constant. The greatest fertility appears to be in the month of May—the first generation. Then there is a sharp drop in the average number of eggs laid, a low point being reached in July.

(2) The first period of the egg-laying curve parallels that of the adult mosquitos, the peak of adults occurring one month after the peak of fertility. This relation does not obtain during the second period. Hence it would seem that some other factor or factors operate.

(3) The generations before and immediately after hibernation show low fertility. This observation was confirmed by a study of the ovaries. Dissection of 50 females belonging to pre- or post-hibernating generations showed : (*a*) that only a portion of the follicles develop, and (*b*) that the actual number of follicles is rather small. In this group of mosquitos the average number in both ovaries was 178, the maximum 201 and the minimum 140. Thus even under the most favourable conditions these females would not lay the same number of eggs as the ones in April-May-June. This reduction in the number of follicles probably depends on factors influencing larval life, as pointed out recently by Weidling.[3]

The percentage of larvae that hatch from eggs laid at various seasons of the year remains fairly constant. Fifty eggs of each batch laid throughout the year were kept separately in Petri dishes, and the number of eggs hatched observed. The

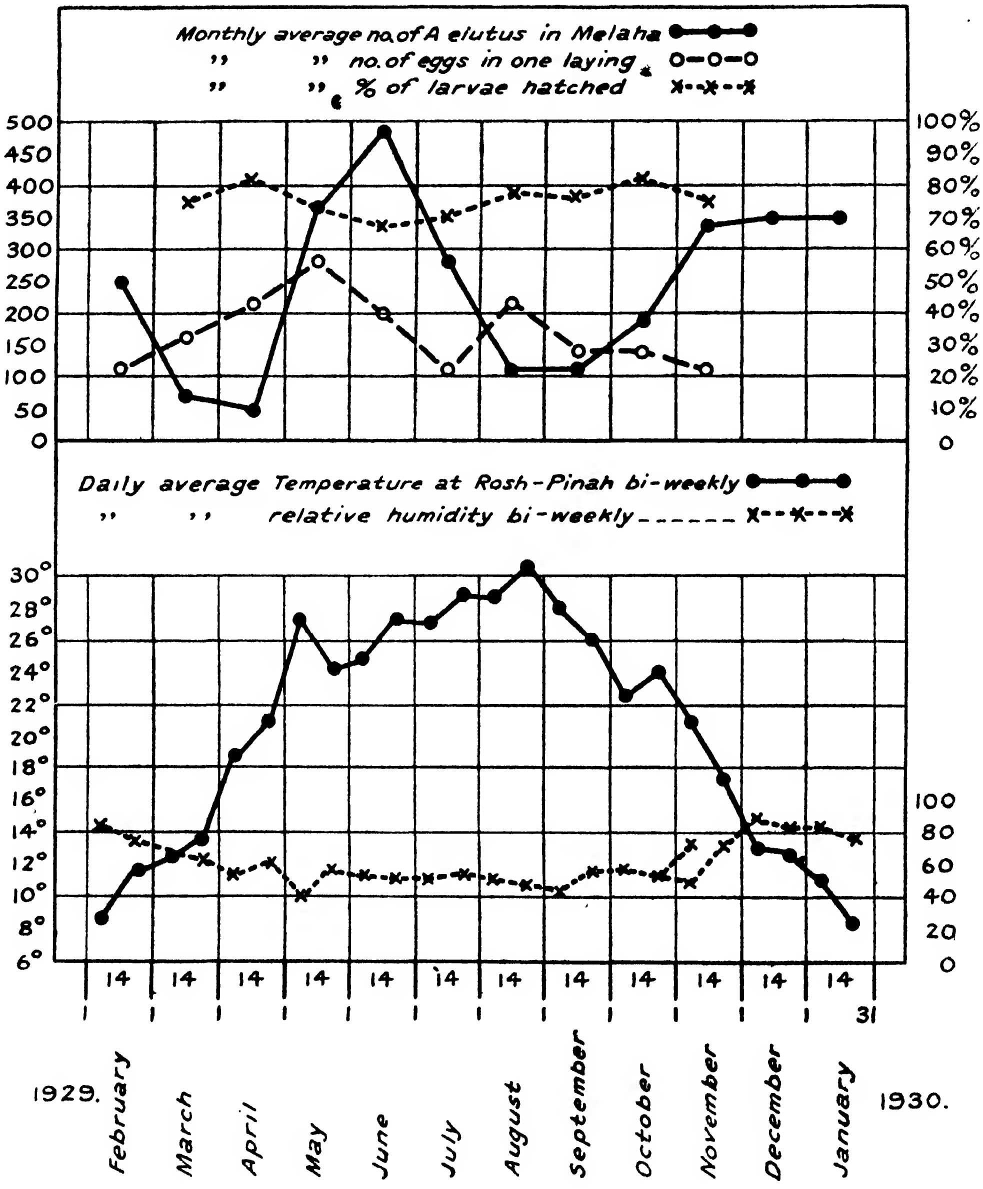

Fig. 1.

corresponding curve (fig. 1) shows that there is little variation in the percentage of hatchings at different periods of the year.

Seasonal Changes in the Eggs of A. elutus.

In 1925 Theodor[4] recorded certain changes in the eggs of *A. elutus*. He noted that during the winter these eggs had floats similar to those of *A. maculipennis*; the floats were smaller during the spring and completely absent at the beginning of May. He suggested that the phenomenon was due to temperature, but did not give

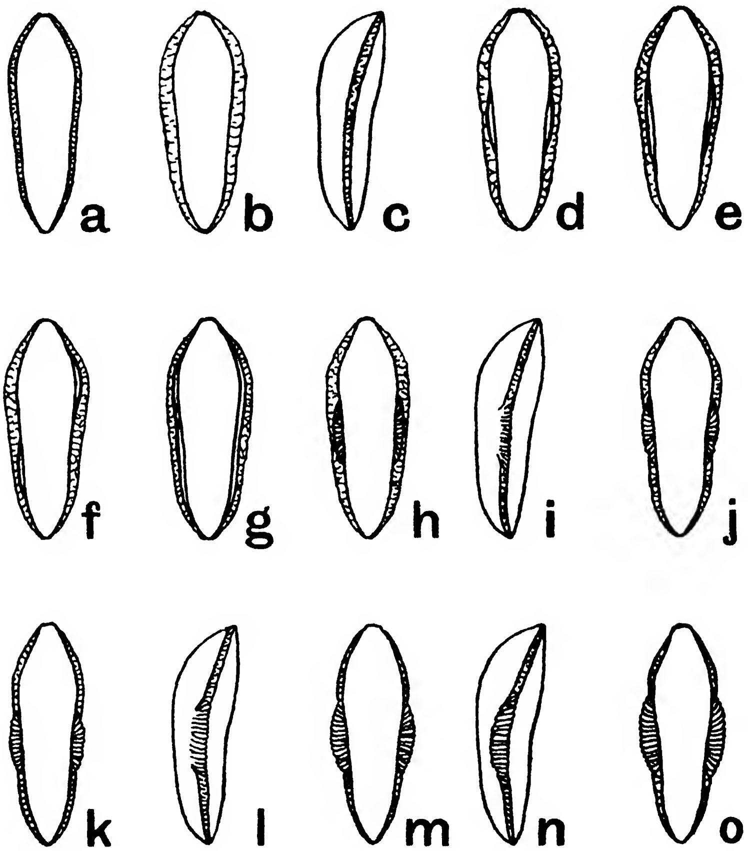

Fig. 2.

Eggs of *Anopheles elutus*, Edw.: *a*, spring egg, no floats, narrow rim; *b*, summer egg, no floats, broad rim; *c*, side view of *b*; *d-e*, first small floats appearing; *f*, irregularly situated floats; *g*, very long floats; *h*, first floats with segmentation, not extending beyond rim; *i-j*, first floats larger than rim; *k-o*, several sizes of winter floats, narrow rim.

any experimental evidence in support of this view, nor did he relate the size of the floats to certain ranges of temperatures. These observations were confirmed by Grassi[5] on mosquitos received from Palestine.

In the course of our observations on the bionomics of *A. elutus* in the Rosh Pinah area nearly 440 batches of eggs were examined, 112 of which matured and were laid under controlled conditions in the laboratory. In the laboratory experiments only

females with undeveloped ovaries which had a fresh blood meal were used. The results are given in Table I.

TABLE I.

Record of 60 Batches of Eggs of A. elutus *deposited in the Laboratory from* 16.x.1929 *to* 26.i.1930.

Date	Average daily temperature in laboratory	Observations
16.x–23.x ...	21·9° C.	First small floats ; broad rim (fig. 2, *b*).
23.x–31.x ...	23·0° C.	Small floats, irregular in shape, size and position ; narrow and long floats. Some larger floats, broad rim. Floats not broader than the rim (fig. 2, *d-h*).
1.xi–8.xi ...	22·5° C.	
8.xi–16.xi ...	—	
16.xi–23.xi ...	19·5° C.	First floats extending beyond rim ; 20.xi (fig. 2, *i-j*).
23.xi–30.xi ...	18·0° C.	
1.xii–8.xii ...	15·0° C.	The floats conspicuously broader than the rim, the latter much narrower than in earlier batches ; 17.xii (fig. 2, *k*).
8.xii–16.xii ...	14·0° C.	
16.xii–23.xii ...	12·0° C.	
23.xii–31.xii ...	12·0° C.	—
1.i–8.i ...	12·0° C	Large floats, narrow rim ; 1.i.30 (fig. 2, *l-m*).
9.i–16.i ...	12·0° C	Very large floats, very narrow rim ; 26.i.30 (fig. 2, *n-o*)
16.i–23.i ...	10·0° C.	
23.i–30.i ...	11·0° C.	—
1.ii–4.ii ...	11·0° C.	—

As can be seen from Table I, egg batches containing eggs with very small floats as well as without floats were first observed on 16.x. At this time the mean temperature was about 23° C. (the temperature was measured 3 times a day and the daily average determined). The floats in these batches appeared as bright patches (colour due to refraction of light by enclosed air) in the grey rim of the egg, the rim at this time being comparatively large and the floats only half as broad as the rim (fig. 2, *d*, *e*). These early floats had no definite localisation ; at times they were situated at the middle of the egg, at others they were shifted more or less to the extremities (fig. 2, *f*). Frequently the floats were very long and narrow, sometimes surrounding the whole egg (fig. 2, *g*). At the end of this period floats appeared in which the segmentation was very marked, although they never extended beyond the rim (fig. 2, *h*).

From 20.xi to about 15.xii the floats were larger, extending somewhat beyond the rim and having definite segmentation, but they were still much smaller than the floats of the egg of *A. maculipennis* (fig. 2, *i*, *j*). From 17.xii to February, when the observations were interrupted, all floats were of about the same size as those of *A. maculipennis* in Europe (fig. 2, *k-o*).

The rim of these eggs became gradually narrower during the winter and was narrowest in the middle of January, when the floats were largest. During the whole spring the rim remained narrow at a time when the floats had already disappeared (fig. 2, *a*). The egg figured by Edwards[6] is a spring egg.

In addition to the observations reported above, in which mosquitos were kept at known temperatures from the beginning of the development of the ovary, 300 batches of females were examined which were caught with ripe eggs. The correlation

between temperature measured in the field and the shape and size of the air-floats of the eggs deposited at that time corresponded with the laboratory observations. The first floats were observed in the middle of October at a temperature of about 25° C. (the place where the females were caught had an average temperature 1·5–2° C. higher than Rosh Pinah). Eggs without floats first appeared on 30.iii at a temperature of about 16° C. The last eggs with floats were seen on the 1.v at a temperature of about 25° C. From October to February the floats increased in size, and from February to May they diminished again ; in February they occupied a quarter to a fifth of the breadth of the egg, in March from a quarter to a tenth, and in April they did not exceed a tenth.

In order to establish definitely the relationship between temperature and the form of the floats, several experiments were undertaken of which the following two were carried through to the end.

Two freshly fed females were kept at a temperature of 23–25° C. in the incubator. After two feeds they deposited eggs with broad rims and either very small floats or without floats. Immediately after oviposition (no. 1, 25.xii, and no. 2, 26.xii) they were removed to the laboratory, where the average temperature was 12° C. Both females fed twice and both laid eggs on 15.i and 26.i respectively. All the eggs in these batches had a narrow rim and big floats very similar in form and equal in size to those of *A. maculipennis*. The average temperature in the laboratory during the period of observation was 10–12° C.

After the second oviposition the two females were again fed and placed in an incubator at a temperature of 23–25° C. Both fed twice ; no. 1 laid eggs on 22.i.30, no. 2 on 2.ii.30. The eggs of no. 1 had a broad rim and small floats not extending beyond the rim and without segmentation. Some of the eggs of no. 2 had still smaller floats than those of no. 1, but a considerable number of them had no floats at all.

These experiments prove that the presence or absence of floats in the eggs of *A. elutus* depends entirely on the prevailing temperature during the development of the ovaries, and confirm the observations made in the field.

As to the significance of this phenomenon, the following suggestion may be put forward. The broad rim of the summer eggs keeps them rather deeply immersed in the water, and as the upper surface of these eggs has a bright white colour, they would seem to a certain degree to be protected from the intense irradiation and heat.

The floats which extend further on the lower surface of the egg, probably keep it higher above the surface of the water. Moreover, the upper aspect of the winter eggs is much darker than that of the summer ones. The winter egg is thus more exposed to the rays of the sun.

The function of the floats is thus to obtain optimal temperature in the cold season, and the loss of floats is a protective adaptation against excessive heat and irradiation.

Relationship between Temperature and Hibernation of A. elutus.

Hibernation of mosquitos was generally considered as a direct consequence of the drop in temperature in the autumn. MacGregor[7] still considers it to be the only cause. Grassi,[8] on the other hand, observed that *A. claviger* resumes sexual activity in the spring at a temperature lower than that at which it starts hibernation in the autumn, and believed that the hibernation of this mosquito was not due to the drop in temperature alone. In Roubaud's opinion[10] low temperature does not induce hibernation, but reactivates the asthenobiotic female.

In northern countries the hibernation of *Anopheles* is characterised by two main features: (1) general lassitude of the insect, (2) suspension of sexual activity. In Palestine, as already pointed out by Kligler,[11] *A. elutus* feeds and moves about during the winter, owing in all probability to the relatively high temperatures which occur now and then during the winter. Thus we have what Kligler[11] calls partial or imperfect hibernation.

We have found that the hibernation of *A. elutus* is modified in so far as the feeding and flying are concerned, but that the suspension of egg-laying is complete; in Palestine it is characterised only by the fact that in the autumn and during the winter the females "may feed several times without maturing ova. The blood then is transformed into reserved materials (fat-body)" (Sella cited by Grassi[8]).

Fat Storage.—In 1929 the first *A. elutus* females with fat-body reserves were seen during the week of 8–16.x (the average day temperature of this week was 23° C.). This temperature average corresponds in the spring to that of the first week of May, when there is a maximum activity of *A. elutus*. With the progress of the cold season the number of females with fat-body reserves increases, and the number in which egg maturing occurs decreases.

TABLE II

Relative Incidence of Females containing Fat and Ova during October–November.

Date of catch	20.x	24.x	1.xi	7.xi	14.xi	21.xi
Females with fat (percentage of total)	54	67	78	75	81	85
Females with eggs (percentage of total)	21	16	5	3	2	0
Total dissected	84	60	115	114	117	92

Table II shows the results of dissections of *A. elutus* females caught in various places in our area both in houses and stables. On 21.xi.1929, 85 per cent. of the females presented fat-body reserves, the remainder being meagre or with fresh blood. Out of 250 females dissected from this date up to 2.ii.1930, not a single one contained maturing eggs.

Sexual Activity.—The sexual activities appear to be resumed in February. In 1929 in Rosh Pinah, the place with the lowest temperature in our area, the first females with maturing eggs were observed on 28.ii (average day temperature 12° C.). At Melaha, another village where the temperature is usually 2° C. higher, females with eggs were found as early as 20.i. In 1930 ripening of ova started simultaneously in both places during the first days of February, owing in all probability to the sudden rise of temperature on the 29th, 30th, 31st January (11°, 15°, 11° being the daily average temperature at Rosh Pinah). On the 2–4.ii, 70 per cent. of *A. elutus* females caught were found to contain blood in various stages of digestion, and 28 per cent. showed marked development of the ovaries. It appears therefore that the resumption of active sexual life takes place in the spring at a temperature considerably lower than that at which it ceases in autumn, although the reactivation seems to be brought about by a rise in the temperature.

The accumulation of fat reserve is closely associated with loss of sexual activity and is gradual. The new-born females, even those born in October, are entirely

meagre. At least 3–4 feeds appear to be necessary for the maximum deposition of reserve material. In October (average day temperature 23° C.) the feeds required for the accumulation of fat-reserves must be frequent, because at this temperature the digestion of the blood is rapid and *A. elutus* females lose the whole of their reserve fat in about eight days. The frequency of feeding decreases with the progressive drop in temperature, and in November 4 per cent. and in December only 2 per cent. of *A. elutus* caught daily showed fresh blood.

With the accumulation of fat-body reserves the abdomen of the mosquito becomes distended. By the degree of distension, provided no eggs or blood, liquid or gases, are contained in the midgut and ventral diverticulum, it is possible to estimate the amount of reserve that a female has accumulated. The abdomen of a meagre female is slender and presents two lateral grooves between tergal and sternal plates of each segment. After the blood of the first feed is digested, the abdomen of an overwintering female is not much more voluminous than that of a meagre one. But the pleurae are distinctly distended and fill out the lateral grooves. In the females that have approximately twice as much fat-body reserve as the above, the abdomen is cylindrical. In the females that have three times as much fat the abdomen shows slight ventral convexity.

Throughout the winter we meet females with varying degrees of fat reserves, and the distribution of these types shows no regularity. This probably depends on the fact that two processes, fat reserve accumulation and its consumption, go on simultaneously. Taking the quantity of fat reserve accumulated by a meagre female after one feed as unity, it is possible to estimate approximately the amount of fat-body reserve per female. Such an estimated average for the various months is shown in Table III.

TABLE III

Degree of Fat Accumulation in A. elutus *Females during the Hibernating Period*

Month	Second half of October	November	December	January
Amount of fat-body reserve per female	1·3	1·65	1·8	1·3
Number dissected	62	92	80	100

There is an increase in the average fat reserves in November and December, due probably to the frequent blood meals, and a decrease in January due to the predominance of fat consumption. Dissections carried out during February have shown that various amounts of fat reserves may still be found in females containing eggs in various stages of development. However, females caught with ripe eggs, or those which had brought the eggs to maturity in the laboratory, no longer contained fat reserves.

Consumption of Fat.—The consumption of fat may be followed in the laboratory when females are kept without food. Such observations indicate that the rate of consumption in an overwintering female depends on the temperature at which it is kept. Females with maximum fat-body reserves kept without food (only water) at a temperature of 12° C. completely lose their fat in 16–21 days, but when kept at a temperature of 23° C. the time required is 8–11 days. The results of these observations are summarised in Table IV.

TABLE IV.

Rate of Consumption of Fat at different Temperatures.

No.	No. of days starved	Temperature at which kept (in C.°)	State of fat reserves on dissection	Stage of ovary on dissection
1	6	27	±1	2
2	6	27	±1	2
3	6	27	—	2
4	16	23	—	2
5	12	23	—	2
6	12	23	—	2
7	9	23	—	2
8	6	23	—	1–2
9	6	23	—	1–2
10	7	20	±1	1–2
11	7	20	±1	1–2
12	10	19	±1	1–2
13	10	19	±1	1–2
14	10	19	±1	1–2
15	10	19	±1	2
16	16	12	±1	1–2
17	16	12	±1	1–2
18	16	12	—	2
19	22	11	—	2
20	22	9	—	2
21	21	9	—	2
22	22	9	—	2
23	21	9	—	2
24	22	9	—	2

Note. ±1 = small quantity of fat reserve, less than 1.

Development of Ova.—It is interesting to note that the ovaries of females with maximal fat reserve which were starved to complete or almost complete loss of their fat reach only stage 2 (Christophers)[12] in their development. In no case were the ovaries found more fully developed.

A similar condition is noted also in nature when one examines the ovaries of the overwintering *A. elutus* during the various months of hibernation. Certain development of the ovaries takes place during the hibernation period ; but at no time during the winter are the eggs brought to maturity. At the beginning of the hibernation the ovaries of all females, whatever amount of fat-body reserve they may have accumulated, are completely transparent, small and with small follicles. They are identical with those of new-born females. With the progress of hibernation, opaque ovaries twice as large as the others, with follicles also twice as large, are met with. These ovaries have reached stage 2. In December one-third and in February two-thirds of all *A. elutus* females examined possessed such ovaries. The development of the ovaries in overwintering *A. elutus* to the second stage may, therefore, be said to proceed along with the digestion of the fat reserve. This development may be hastened in the laboratory by starvation at a higher temperature, but occurs more slowly in nature as a result of the slow reserve consumption.

Final maturing of the ova apparently occurs only after a blood feed, and consequently it seems that a blood feed is essential before the overwintering mosquitos lay their ova.

Summary.

(1) *A. elutus* females in Palestine show seasonal variations of fertility, but these do not appear to explain fully the distribution of adults throughout the year.

(2) Females of the overwintering generations show low fertility. This depends probably on conditions of larval life.

(3) The seasonal changes in the egg of *A. elutus* in Palestine are due to temperature variations. It is suggested that these changes are protective adaptations against cold in winter and excessive heat and irradiation in summer.

(4) The entering of the hibernation stage of *A. elutus* in Palestine cannot be considered as a pure consequence of the low temperature in autumn, since spring activity begins at a much lower temperature.

(5) During hibernation the females feed, but do not bring eggs to maturity ; the blood is used for fat accumulation.

(6) During the second half of the hibernation period the females lose their reserve materials.

(7) Full fat females starved in the laboratory lose their fat-body reserves, and simultaneously their ovaries develop to stage 2. Under the prevailing temperature the process requires about 3 weeks.

(8) A slow development of the ovary is going on during hibernation, but never proceeds beyond the second stage. The ovaries in a large percentage of females reach this stage at all times when reactivity occurs at the end of the hibernation period.

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ON THE REPRODUCTION OF ORGANISMS WITH OVERLAPPING GENERATIONS.

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(With an Appendix by H. E. Soper.)

INTRODUCTION.

In the great majority of organisms, the reproducing individual does not engender all of its progeny simultaneously. Between the beginning and the end of the reproductive period there is usually a certain interval of time, during which the production of offspring continues in a manner depending, on the one hand, upon the specific characteristics of the organism, and on the other, upon the conditions under which it lives. From this simple fact follow some interesting consequences.

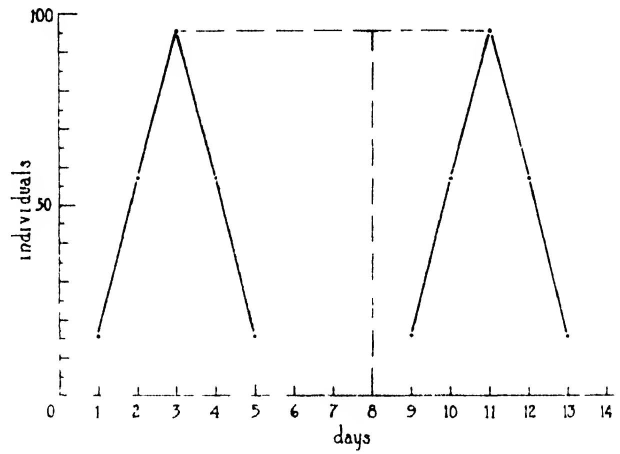

Fig. 1. Curves of births and deaths in the fourth generation of a species, whose generation formula is $T^1+T^2+T^3+T^4$. The ordinates represent the number of individuals, the abscissae, the successive days in the reproductive period. The left-hand curve represents births, the right-hand curve, deaths.

If the successive generations are separated by a long interval of time and conditions during this interval are of such a nature that the organism is inactive and in the condition of obligatory dormancy, known as diapause, then, in spite of the increase of the population, the generations will remain separate and distinct, and a comparison of the total populations in the successive reproductive periods will enable us to determine the rate of increase.

On the other hand, if the interval between generations is short and favourable to activity and the organism does not pass through a period of obligatory dormancy at this time, then, as the species increases, the successive generations will come to overlap, and the amount of overlapping will increase progressively as time goes on.

This is primarily due to the fact that when there is reproduction over a period of time-intervals, in a typical individual of the species, and conditions remain constant, then the number of time-intervals during which births occur will increase from generation to generation. In this way there will be produced a lengthening of the reproductive period for the whole mass of individuals; and this will cause a diminution of the intervals between stages in the same generations, and between generations, so that individuals belonging to different stages of development, and to different generations, will be found simultaneously in the field.

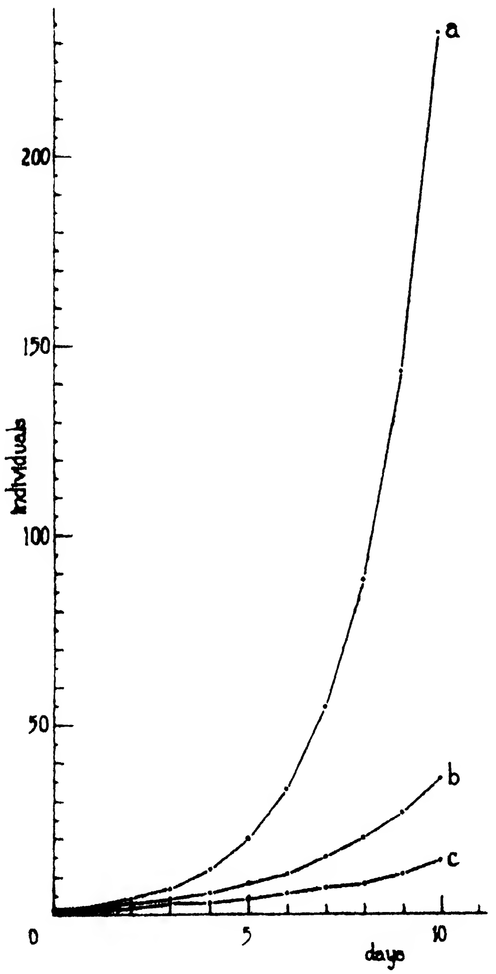

Fig. 2. Comparative curves of total births when the generation formulae are T^1+T^2 (curve *a*), T^2+T^3 (curve *b*), and T^3+T^4 (curve *c*). In this and succeeding figures, the ordinates represent number of individuals, the abscissae, the successive days in the reproductive period.

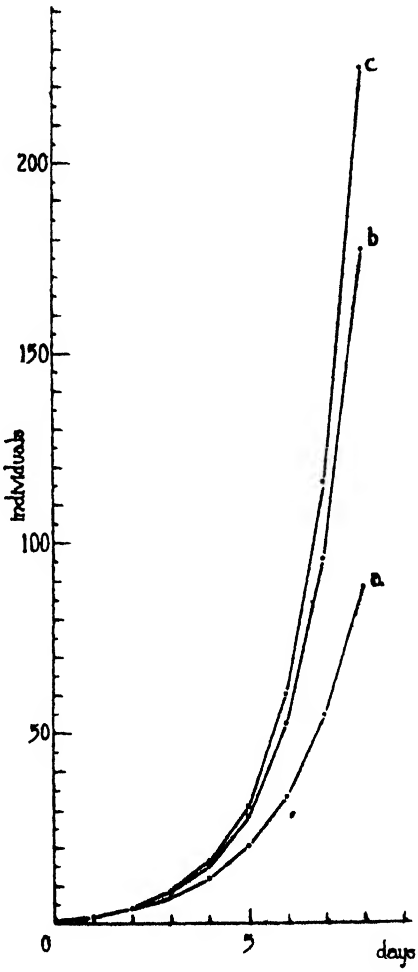

Fig. 3. Comparative curves of total births when the generation formulae are T^1+T^2 (curve *a*), $T^1+T^2+T^3$ (curve *b*), and $T^1+T^2+T^3+T^4$ (curve *c*).

On account of these facts the calculation of the number of progeny and of the number of individuals in successive stages, existing at any given moment, presents serious difficulties, which make both the practical and the theoretical treatment of the subject laborious. Some years ago I began to study the matter and succeeded in getting the process of calculation into a form in which the required data could be obtained, but the method of calculation was extremely tedious. The results obtained were accordingly submitted, through the kindness of Professor M. Greenwood, of the Department of Epidemiology and Vital Statistics of the London School of Hygiene

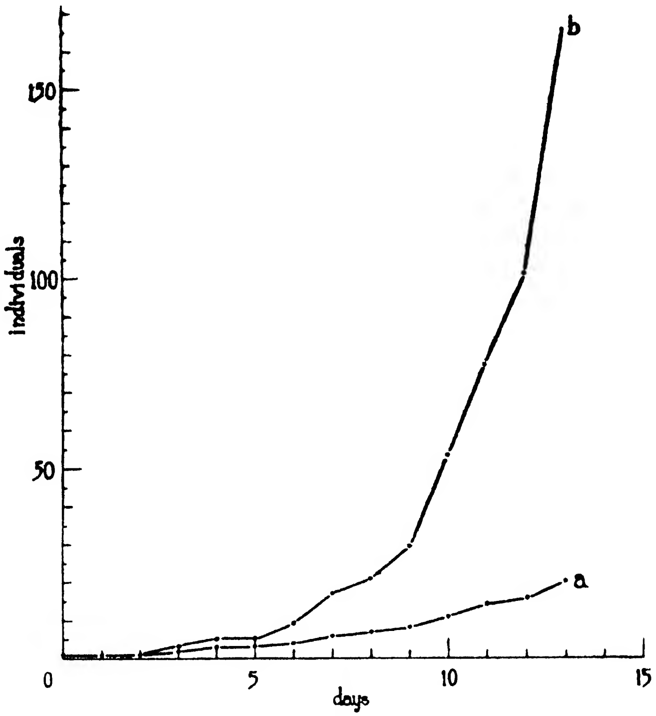

Fig. 4. Comparative curves of total births when the generation formulae are T^3+T^4 (curve a) and $2(T^3+T^4)$ (curve b).

and Tropical Medicine, to Mr. H. E. Soper.* Within a few days I received from Mr. Soper a communication, in which he explained and developed in detail an extremely elegant method of dealing with the problem. It is this method which I have utilised in this paper. I have added such explanations as seem to me necessary in order to make the process of reasoning clear to those who, like myself, have little knowledge of mathematics, and have worked out a series of examples to show how the method may be employed in entomological problems. The credit for the solution utilised is entirely due to Mr. Soper, and I am glad to have this occasion of thanking him for the kind and patient interest he has shown in the problems submitted to him.

* While this paper is passing through the press I have learnt with the greatest regret of the death of Mr. Soper.

For the graphs illustrating the paper I am indebted to Dr. G. Salt.

The first part of the paper is devoted to an exposition of the problem; the second part to the methods which can be used in dealing with it; and the third part to an application of these methods. The mathematical theory of the method is given by Mr. Soper in the Appendix.

The object of the paper is, in the first place, to enable the entomologist to investigate the natural control of insects with reproduction of this type; and, in the second place, to show how variation in the length of the pre-reproductive and reproductive periods, and in the production of offspring, affect the increase in population. When the length of life and of the pre-reproductive and reproductive periods

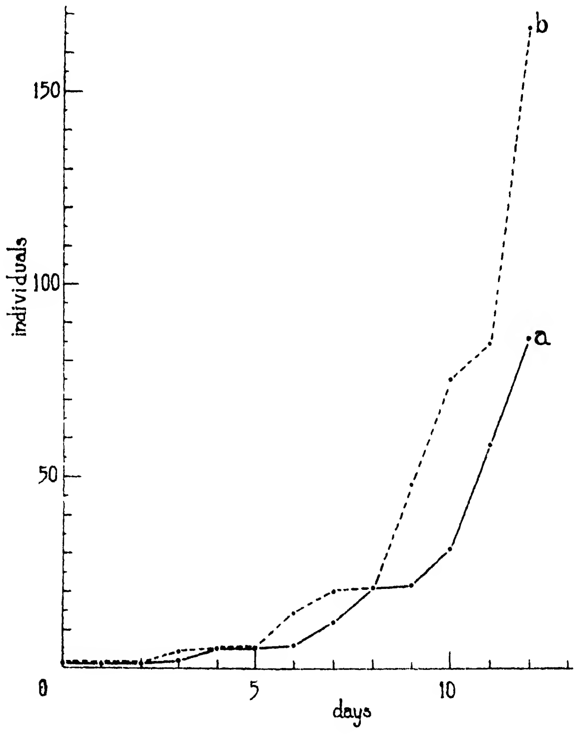

Fig. 5. Comparative curves of total births when the generation formulae are 1 $T^3+3\ T^4$ (curve *a*) and 3 $T^3+1\ T^4$ (curve *b*).—Note that the curves do not intersect.

have been determined, and the average daily production of progeny is known, we can calculate from the formulae given the daily births or the daily population of individuals of all ages, when no causes of mortality intervene. By comparing the figures with those obtained in an actual experiment, we can then determine when causes of mortality begin to operate and get some idea as to the nature and effect of the controlling factors which come into play at any given date. Organisms with overlapping generations are particularly suitable for work of this kind, because of their rapidity of reproduction, but the complex way in which their populations increase has, hitherto, constituted a very serious obstacle to their study. The formulae

developed by Mr. Soper enormously simplify the problem and constitute, I believe, a very important contribution to our methods of study of the process of natural control.

I.

Let us suppose, to begin with, that we have an *initial organism* or stem-mother, producing d offspring per day* during a certain period, which we may call k days

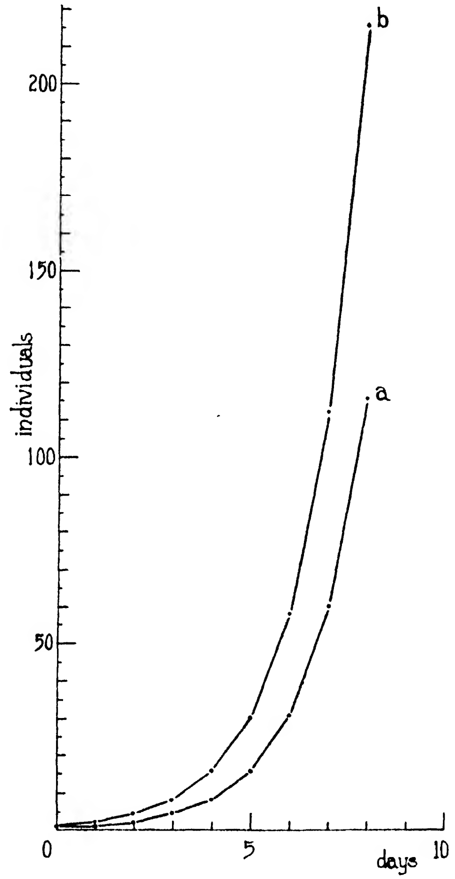

Fig. 6. Comparative curves of daily births (curve a) and total population of all ages (curve b) when generation formula is $T^1 + T^2 + T^3 + T^4$.

for the moment; and let us suppose that the reproducing individual dies on the day it has produced its last offspring. Then, in the first generation, if we put $k=4$, for the sake of simplicity, we shall have births occurring as follows :—

Day ...	1	2	3	4	5	6	7	8	9	10
G.I ...	d	d	d	d						

* Instead of saying "per day," we could say "per interval of time," including a period either less than or greater than a day; the course of the argument would be the same.

Now suppose that both the organisms produced in the first generation and the environmental conditions under which they live remain identical. The group of organisms produced on the second day will reproduce a day later than those produced on Day 1; the group produced on the third day, two days later than those produced on Day 1, and so on. The second generation, produced by the reproduction of the groups occurring on the successive days, will thus be as follows, since each individual of the group of d produces d offspring :—

	Day	1	2	3	4	5	6	7	8	9	10
G.II	... 1	d^2	d^2	d^2	d^2						
G.II	... 2		d^2	d^2	d^2	d^2					
G.II	... 3			d^2	d^2	d^2	d^2				
G.II	... 4				d^2	d^2	d^2	d^2			
Total		$1d^2$ ·	$2d^2$ ·	$3d^2$ ·	$4d^2$ ·	$3d^2$ ·	$2d^2$ ·	$1d^2$			

In the next generation the process will obviously continue in the same way; during the first reproductive period $1d^2$ individuals will produce d offspring per day; during the second period $2d^2$ will produce d each per day; during the third period $3d^2$ will produce d per day, and so on—the result being as follows :—

	Day	1	2	3	4	5	6	7	8	9	10
G.III	.. 1	d^3	d^3	d^3	d^3						
	2		$2d^3$	$2d^3$	$2d^3$	$2d^3$					
	3			$3d^3$	$3d^3$	$3d^3$	$3d^3$				
	4				$4d^3$	$4d^3$	$4d^3$	$4d^3$			
	5					$3d^3$	$3d^3$	$3d^3$	$3d^3$		
	6						$2d^3$	$2d^3$	$2d^3$	$2d^3$	
	7							d^3	d^3	d^3	d^3
Total		$1d^3$ ·	$3d^3$ ·	$6d^3$ ·	$10d^3$ ·	$12d^3$ ·	$12d^3$ ·	$10d^3$ ·	$6d^3$ ·	$3d^3$ ·	$1d^3$

When we compare the series of births in the successive generations the first thing that we notice is that the number of days (or time-intervals) on which births occur becomes greater in each generation. Thus, as an organism increases in numbers, the length of time during which births occur in the field will also increase, from generation to generation, and so will the length of time during which the successive developmental stages are found, without there being, necessarily, any deviation whatever from the specific reproductive habits, or any change in the environmental conditions; or, in other words, any real irregularity in the course of events.

Furthermore, if attempts to evaluate the population in comparable areas are made throughout the whole period covered by each generation, it will be found that whereas in the first generation the curve of daily births is a straight line, in the successive generations it is a curve, having a maximum extending over one or two time-intervals. If the number of time-intervals in the reproductive period is *even*, the *curves of every second generation* have maxima extending over two time-intervals, while the *curves of the alternate generations* have maxima occupying only one time-interval. If the number of time-intervals in the reproductive period is *odd*, the *curves of all generations* have maxima occupying only a single time-interval.

The general character of the change from generation to generation being the same in all cases, a sufficiently accurate idea of it can be obtained by the study of any

example. Taking the reproductive period as of 2 days, inserting the d, d^2, d^3, . . ., etc., and giving d the value of 2, we obtain the following figures for the series of births :—

DAY	1	2	3	4	5	6	7	8	9	10
G.I ...	2	2								
G.II ...	4	8	4							
G.III ...	8	24	24	8						
G.IV ...	16	64	96	64	16					

Thus, when we consider the curves of the series of births in the successive generations, we find that not only does the point of origin of the successive curves become higher and, as we have already mentioned, their trajectory longer, but their slope becomes steeper.

Therefore, as soon as an organism begins to increase in numbers, under the conditions described, we shall find, if we make collections at suitable intervals at comparable areas throughout the period of reproduction, that the number of births per unit area in the successive intervals is not constant, but rises to a maximum and afterwards falls ; and since, other things being equal, the population of the latter developmental stages depends upon the number of births, this will also be true for the later stages, so that we shall have *maximum periods* of oviposition, of hatching, of the apparition of larvae at any given stage, of pupation, of emergence, and so on. The greater the number of generations since the beginning of the increase, the more marked will this curve be, or, in other words, the higher its " peak " in comparison with its initial and terminal portions.

Here, again, we must insist upon the fact that this apparent complexity and irregularity of the seasonal incidence may be quite illusory, and does not necessarily indicate or prove that any given individual is in fact ovipositing more rapidly at a given moment, or that the tendency to pupation becomes more marked at a certain time of the year, irrespective of the age of the individual concerned. All the phenomena described may occur under perfectly homogeneous conditions, without any variation in the habits of the species concerned.

From these facts we can deduce a simple method of interpreting and computing the value of collections in the field (fig. 1). If we draw the curve for Generation IV in the species with the two-day reproduction period, for which the figures are given above, and suppose that the length of the life-history from birth to death is approximately constant, then a line drawn for the same distance along an abscissa from each point of the curve will give us the curve of the deaths, arranged on the days in which they occur.

We can read off on the ordinate for any given day the number of individuals of each stage we ought to find in an area, comparable to that in which the first collection was made. Thus on Day 8 we ought to find :—

16 individuals 7 days old ;
64 individuals 6 days old ;
96 individuals 5 days old ;
64 individuals 4 days old ;
16 individuals 3 days old.

Furthermore, in a lot comprising a smaller or larger number of individuals than the number mentioned, the *proportion* belonging to each stage should be the same.

Other things being equal, this would permit us to discover any decrease or increase in the number of individuals belonging to any given stage. Thus, if on the eleventh day the number of the eighth stage individuals was not 96, but only 50, while the number of other stages was as expected, then we should know that a cause producing a high mortality in individuals of *only one stage was operative on only a single one of the days in which the susceptible stage was present.*

This is easily demonstrated. If the cause had affected other individuals of other stages, the numbers of the individuals which had belonged to these stages would not now be as expected; and, on the other hand, if the cause had operated on more than one day it would have found additional individuals in the stage susceptible to it, which would mean at the time of collections a deficit in groups other than the one found to be below the normal level. With this information we might conceivably be able to track down the cause of mortality observed.

Again, provided the reproductive rate is known, the data obtained from the collections for any given generation can be utilised to determine the possible incidence of the individuals of the following generation, the method followed being, of course, simply that utilised in the construction of the birth-series for the successive generations in the examples given above.

It is clear from what had preceded that the extension of the reproductive phenomenon over a period of time renders probable an overlapping of the various stages of the life-history, since the first individuals produced have developed considerably by the time the latest individuals have come into existence.

Furthermore, since the number of time-intervals during which births occur increase from generation to generation, it is also evident that, as time goes on, the interval between the end of one generation and the beginning of another will become smaller and smaller, and then disappear, after which the successive generations will overlap. The overlap will become greater and greater as the generations succeed one another. Finally, the number of generations overlapping in a given time-interval will also become greater, though the rate of increase is not a smooth and regular one.

Thus, suppose the pre-reproductive period of a species is of two days (including day of birth) and the reproductive period also two days, each individual producing d births per day, the succession of events will be as follows:—

The first and second generations do not overlap, but the second and third overlap on one day, the third and fourth on two days, the fourth and fifth on three days, the fifth and sixth on four days, the nth and $(n+1)$th on $(n-1)$ days. On the first four days individuals of only one of the two generations produced are found on any one day; on the fifth day individuals of G.II and G.III co-exist; on the seventh and eighth days individuals of G.III and G.IV, on the ninth and tenth days individuals of G.IV and G.V; on the eleventh day individuals of G.IV, V, and VI, and on the seventeenth day individuals of G.VI, VII, VIII, and IX.

II.

It will be evident from what has preceded that the direct calculation of the progeny produced day by day in the successive generations, to say nothing of the total number of progeny produced by all generations taken together, or, to take the most difficult case of all, of the total population, including both the newly born and the older individuals, is a very complex matter. In order to deal with the problem it is, therefore, necessary to simplify the operation.

It is, of course, possible to represent the increase in population by using the compound interest formula, according to which the number of individuals existing at any given moment is given by the equation

$$N_1 = N_0 \epsilon^{Kt}$$

Where N_1 is the population at the moment considered, N_0 the initial population, t the number of time-intervals (hours, days, years, etc.), ϵ the incommensurable number 2·71828 . . ., and K a constant depending upon the particular case considered. This formula is, however, not satisfactory for experimental work. In the first place, the constant K cannot be determined until the growth of the population under certain definite conditions has been studied during a considerable period; in

the second place, no intelligible significance can be attached to the constant after its value has been determined; in the third place, the growth of the population is considered in this formula to be at every moment proportional to the size of the population, which is not true except with large numbers and over long periods, and cannot be safely taken as a basis for the examination of experimental data. Thus, using the figures for births in the last example given in this paper, we obtain values from K ranging from 0·652 to 0·693. The former value is valid when the population reaches a high level, but under such conditions accurate analytical experimental work is not possible. The number of individuals at the end of five time-intervals might be anything from 208 to 255. It is therefore necessary to deal with the reproductive process as a discontinuous phenomenon.

If the reproductive rate is regularly d per day or "time-interval," so that the coefficient of d in the first series is uniformly 1, then the coefficients for G.I, if the reproducing life is three days, may be written—

$$CG_1=1,\ 1,\ 1.$$

From these coefficients of G_2 may be derived as follows :—

$CG_2=\cdot1,\ 1,\ 1+\cdot0,1,1,1+\cdot0,0,1,1,1,=\cdot1,2,3,2,1,$

and from these, those of G_3 as follows :—

$CG_3=\cdot1,2,3,2,1+\cdot0,1,2,3,2,1+\cdot0,0,1,2,3,2,1=\cdot1,3,6,7,6,3,1.$

If the reproducing life is 2 days, the formula for CG_1 is 11 ; and those of CG_2 are derived thus :—

$CG_2=\cdot1,1+\cdot0,1,1=\cdot1,2,1$;

$CG_3=\cdot1,2,1=\cdot0,1,2,1=\cdot1,3,3,1.$

The number of terms to be added in each addition is equal to the number of days or "time-intervals" in the reproducing life, and each term is like the preceding, but carried one place to the right.

If the reproductive rate in the first instance is not d per day, but ad, bd, cd, and fd, as d, $2d$, $3d$, $4d$, the rule is—

$$\begin{aligned} CG_2 &= \cdot1,2,3,4,+2(\cdot0,1,2,3,4)+3(\cdot0,0,1,2,3,4)+4(0,0,0,1,2,3,4) \\ &= 1,4,10,20,25,24,16, \text{ and so on.} \end{aligned}$$

The method of finding the coefficients is thus extremely simple. The process may, however, be laborious. Suppose the reproductive life were of 30 days and we wished to calculate the series for the tenth generation. The number of terms in the initial series would thus be 30, but it would increase $(30-1)=29$ per generation, having 291 terms in the tenth generation. Furthermore, in each generation there would be 30 rows of such terms to add.

The process can be materially simplified by deriving the coefficients for a given generation directly from those of the preceding generation. If an adding machine, which prints its results, is used, this can be done quite rapidly.

Suppose that the formula for the births in G is

$G_1=1d+1d+1d+1d+1d.$

Then, as shown above, the formula for G will be—

$G_2=1d^2+2d^2+3d^2+4d^2+5d^2+4d^2+3d^2+2d^2+1d^2.$

In order to obtain the coefficients for G_3 from those of G_2, we have only to note that the coefficient of the first term in G_3 is equal to that of the first term in G_2; the coefficient of the second term of G_3 is equal to the sum of the first two of G_2; that of the third term in G_3 is equal to the sum of the first three of G_2, and that of the fifth in G_3 to the sum of the first five in G_2; that of the sixth in G_3 to the second five in G_2; that of the fifth last in G_3 to the sum of the last five terms in G_2; of the fourth last in G_3 to the sum of the last four terms in G_2, and so on, the end of the series being obtained just like the beginning. In every generation the number of terms which must be added to obtain a coefficient is equal to the number of "time-intervals" in the reproductive period.

When an adding machine is used the process is one of simple addition until the rth termed is obtained (r=number of "time-intervals" in the period of reproduction), after which the process consists in adding the following term to the coefficient just obtained, and subtracting the nth term back. Thus, taking the case where there is a reproductive period of four days, and the coefficients of d in G_2 are—

$$G_2=1,2,3,4,3,2,1\ ;$$

the coefficients for G_3 are obtained as follows :—

$$\begin{aligned} 1&=1\\ 1+2&=3\\ 3+3&=6\\ 6+4&=10\\ 10+3-1&=12\\ 12+2-2&=12\\ 12+1-3&=10\\ 10-4&=6\\ 6-3&=3\\ 3-2&=1 \end{aligned}$$

The mechanical operation is very simple and rapid. In order to avoid mistakes, a slip of paper with dots at the spaces containing figures to be added and subtracted can be prepared and moved down the page, as the work proceeds. The results can be checked by adding the coefficients when the sum for the nth generation should be r^n, where r is the number of days in the period of reproduction, as in the above example, where the sum of the coefficients is—

$$64=4^3.$$

If the process is continued, O should ultimately be obtained. On calculating machines with a revolution register, this will also register O when the operation is complete, since, as the above example shows, the number of positive revolutions is equal to the number of negative revolutions.

Since the length of the pre-reproductive period does not affect the coefficients of d and its powers, the latter can be obtained once and for all the successive generations of a species for which the length of the reproductive period and the number of offspring produced per day are known. Once this has been done, the coefficients with the corresponding power of d could be written on long strips of cardboard, arranged so as to slide one beneath the other in a frame. By spacing the strips and summing the lots of progeny vertically, the effect of variation in the length of the pre-reproductive period on the increase in the numbers of births could be studied.

However, as already indicated on page 155, the above method of finding the coefficients in the series for the successive generations is not valid if the number of progeny produced on successive days is not the same. Thus, if in G_1 we have—

$G_1=\cdot 1,4,6$, the progeny for G_2 are not

$$\begin{aligned} G_2&=\cdot 1,4,6+\cdot 0,1,4,6+\cdot 0,0,1,4,6\\ &=1,5,11,10,6=33, \text{ but}\\ G_2&=1(\cdot 1,4,6)+4(\cdot 0,1,4,6)+6(\cdot 0,0,1,4,6)\\ &=\cdot 1,4,6+\cdot 0,4,16,24+\cdot 0,0,6,24,36\\ &=1,8,28,48,36,=121. \end{aligned}$$

In such cases it is necessary to utilise the cumbersome method first indicated.

The writer was unable to circumvent these difficulties ; but they are all eliminated by the method devised by Mr. Soper. This method is as follows :—*

Suppose the ancestor or stem-mother is born on T^0, and that we represent the successive days or "time-intervals" on which reproduction takes place by

* The process given here is, as a matter of fact, simply a special application of Mr. Soper's method of Formulation by Objective Symbols, which he has discussed in detail in a special work (Frequency Arrays, Camb. Univ. Press, 1922).

T^1, T^2, T^3, T^4, . . . meaning the first, second, third, fourth, etc., days, and suppose one offspring is produced each day. Suppose the reproductive period is one of four days, and the pre-reproductive period is of one day, including the day of birth, then the first generation, $=G_1$ may be written—

$$G_1 = 1T^1 + 1T^2 + 1T^3 + 1T^4.$$

Now the one individual born on T^1 will begin to reproduce on T^2 and from thenceforward during four days; the one individual born on T^2 will begin to reproduce on T^3 and from thenceforward during four days; and similarly, for the individuals born on T^3 and T^4, which begin reproducing on T^4 and T^5 respectively. Thus, writing the series of births for G^2 we have—

$$\begin{aligned} G_2 = 1T^2 &+ 1T^3 + 1T^4 + 1T^5 \\ &\quad 1T^3 + 1T^4 + 1T^5 + 1T^6 \\ &\qquad 1T^4 + 1T^5 + 1T^6 + 1T^7 \\ &\qquad\quad 1T^5 + 1T^6 + 1T^7 + 1T^8 \\ \hline & 1T^2 + 2T^3 + 3T^4 + 4T^5 + 3T^6 + 2T^7 + 1T^8 \end{aligned}$$

which is—

$$= (T^1 + T^2 + T^3 + T^4)^2.$$

In G^3, the one individual produced on T^2 will reproduce on four succeeding days, and similarly, for the two produced on T^3, the three produced on T^4 and so on; and if these series of births are written out and added as before, we obtain—

$$\begin{aligned} G_3 &= 1T^3 + 3T^4 + 6T^5 + 10T^6 + 12T^7 + 12T^8 + 10T^9 + 6T^{10} + 3T^{11} + 1T^{12} \\ &= (T^1 + T^2 + T^3 + T^4)^3. \end{aligned}$$

It is clear that, in general, we have—

$$G_n = (T^1 + T^2 + T^3 + T^4)^n,$$

and that by multiplying this out, or, as the mathematicians say, "expanding it," we shall obtain a series of T's multipled by numbers, or coefficients in which the index of T designates the *day* and the coefficient gives the number of births on that day in the generation considered.

From this simple case all others may readily be derived without any alteration in the reasoning.

Thus, suppose the pre-reproductive period is of three days, including the day of birth, and the reproductive life is of four days, as before. If the original ancestor or stem-mother was born on T^0 (an assumption made in the first case), then its first offspring would be produced, not on T^1 but on T^3, and the first generation would be written—

$$G_1 = (1T^3 + 1T^4 + 1T^5 + 1T^6);$$

then the individual produced on T^3 would begin reproducing on T^6, and we should obtain, by proceeding as before, a series for the second generation equivalent to—

$$(1T^3 + 1T^4 + 1T^5 + 1T^6)^2.$$

Finally, if, instead of one birth on each day, we assume d on each day, we should obtain—

$$\begin{aligned} G_1 &= d(T^1 + T^2 + T^3 + T^4); \\ G_2 &= d^2(T^1 + T^2 + T^3 + T^4)^2; \\ & \\ G_n &= d^n(T^1 + T^2 + T^3 + T^4)^n; \end{aligned}$$

while if the number of births varied from day to day, so that we had—

$G^1 = (aT^1 + bT^2 + cT^3 + dT^4)$; we shall have

$$= (aT^1 + bT^2 + cT^3 + dT^4)^n.$$

Suppose that on one or more days in the reproductive period no progeny are produced. This is allowed for simply by omitting these days. Thus, in the last series mentioned, let $b=0$. The formula for the nth generation will then be :—

$$G_n=(aT^1+cT^3+dT^4)^n.$$

In the case of a long reproductive period, the process of multiplying out such expressions is laborious, but it can be simplified to some extent by utilising the well-known *multinomial theorem.*

To find the number of terms in the series for any generation : If the birth formula of the species is—

$$(T^1+T^2+T^3+T^4),$$

then the series for the third generation is—

$$(T^1+T^2+T^3+T^4)^3, \text{ as already shown.}$$

The first term is .... $T^{(1)3}$.

The last term is .... $T^{(4)3}$.

The number of terms in the series is obviously $3(4-1)+1=10$.

Supposing the series is $(T^1+T^2+\ldots\ldots T^l)^n$, containing l terms ; then the number of terms in the series for the nth generation is—

$$\{n(l-1)+1\}.$$

What has preceded covers fully the series of births (or production of offspring) in each generation considered separately ; but it does not give us any information as to the overlapping of the generations, nor does it enable us to calculate directly the *total* number of births produced by the individuals of all the different generations which happen to be reproducing on any given day ; and that individuals belonging to different generations will be producing simultaneously we have already seen.

In order to find out how many generations co-exist on any given day, the following method may be adopted.

Divide the number of the day by the index of the *last term* in the generation formula. If there is no remainder, the answer will be *the number of the earliest generation still existing* on the day considered. If there is a remainder, the number of the earliest generation still existing will be one more than the answer.

To obtain *the number of the latest generation which is proceeding on the day considered,* divide the number of the day by the index of the *first term* in the generation formula ; the answer, neglecting any remainder, is the number of the latest generation which is proceeding.

Knowing the earliest and the latest generations existing on the day considered, the total number of generations co-existing on that day can be found.

Thus, suppose the generation formula is—

$$G=T^1+T^2+T^3+T^4,$$

the number of the earliest generation existing on the 24th day will be $\frac{24}{4}=6$:

the number of the latest generation proceeding will be $\frac{24}{1}=24$:

there will thus be 19 generations co-existing on the 24th day.

If the generation formula is —

$$G=T^2+T^3+T^4+T^5,$$

the number of the earliest generation existing on the 17th day will be $\frac{17}{5}=3+1=4$.

The last day on which generation three existed was the fifteenth. Generation four still exists on the 20th day ; but it is the earliest one still existing on the 17th day.

The number of the latest generation existing on the 17th day is $\frac{17}{2}=8$. There is a remainder of one, because the eighth generation really began on the 16th day. In all $(8-4+1)=5$ generations co-exist on the 17th day.

If, taking the successive generations in the example already studied, we write them down and add, we have—

$$G_1+G_2+G_3=(T^1+T^2+T^3+T^4)+(T^1+T^2+T^3+T^4)^2 +(T^1+T^2+T^3+T^4)^3.$$

It is obvious, from what has preceded, that by expanding these expressions and adding up all the T^1, T^2, T^3 .... T^{12} we shall get the number of births produced by all the individuals of all the generations existing simultaneously on any given day, up to and including the third generation.

If we designate—

$$T^1+T^2+T^3+T^4 \text{ by } G$$

so that we have

$$G_1=G$$
$$G_2=G^2$$
$$G_n=G^n,$$

we can write

$$G_1+G_2+G_3=G+G^2+G^3$$
$$=\frac{G(1-G^3)}{1-G}$$

by the usual rule for the summation of a geometrical series.

But this formula does not represent the *total* number of individuals produced up to the day on which G_3 ends (T^{12}), because by that time generations G_4 to G_{12} inclusive will already have begun.

Let us, therefore, take the sum of $G_1+G_2+G_3+$............to n generations. We have, including the original ancestor or stem-mother—

$$1+G_1+G_2+G_3+.........+G_n=1+G+G^2+G^3+.........+G^n$$
$$=\frac{(1-G^n)}{(1-G)}.$$

We have also $G=T^1+T^2+T^3+T^4$, which may be written—

$$\frac{T-T^5}{1-T}$$

as division will prove.

Substituting, we have—

$$1+G_1+.........+G_n=\frac{1-\left\{\frac{T^1-T^5}{1-T}\right\}^n}{1-\left\{\frac{T^1-T^5}{1-T}\right\}}$$
$$=\frac{(1-T)\ (1-\{T^1+T^2+T^3+T^4\}^n)}{1-2T+T^5}$$
$$=\frac{(1-T)\ (1-T^n\text{—higher powers of } T)}{1-2T+T^5}$$
$$=\frac{(1-T-T^n\text{—higher powers of } T)}{1-2T+T^5}.$$

Now here, exactly as in the case of—

$$\left\{\frac{T-T^5}{1-T}\right\}.$$

we have only to divide the numerator by the denomination to get a series in which the index of T will designate the day and the coefficient of T the total number of births for that day.

If we suppose n is infinitely large, then T^n and the powers of T following it may be neglected, and the expression becomes—

$$\frac{(1-T)}{(1-2T+T^5)}$$

which is the same thing as

$$1+G+G^2+G^3+\ldots\ldots\ldots+G^n$$

summed to infinity as a diminishing series

$$=\frac{1}{1-G}.$$

When we substitute—

$$\left\{\frac{T-T^5}{1-T}\right\}$$

for G.

The same method of procedure, up to this point, may obviously be used whatever the initial value of T, whatever the number of terms in the series for G_1, and whatever the daily birth rate, provided it is constant and regular.

Thus we have—

$$G_1=(T^3+T^4+T^5+T^6+T^7)\text{ ; this can be written}$$

$$G_1=T^3\frac{(1-T^5)}{1-T}=\frac{T^3-T^8}{1-T};$$

so that $G^1+G^2+G^3+\ldots\ldots\ldots\ldots$

$$=\frac{1-T}{1-T-T^3+T^8}$$

If we have—

$$G_1=(dT^3+dT^4+dT^5+dT^6+dT^7)=\frac{d(T^3-T^8)}{(1-T)}$$

the formula will be—

$$1+G_1+G_2+G_3+\ldots\ldots\ldots\text{ etc.}=\frac{1-T}{(1-T-dT^3+dT^8)}$$

If the number of births on the successive days of the period of reproduction is not the same, suppose these births to be a, b, c, d, as before. We then have—

$$G=aT^1+bT^2+cT^3+dT^4$$

$$G_2=(aT^1+bT^2+cT^3+dT^4)^2=G^2\text{ etc., and}$$

$$1+G_1+G_2+\ldots\ldots\ldots=\frac{1}{1-G}$$

$$=\frac{1}{1-(aT^1+bT^2+cT^3+dT^4)}$$

which will be valid even when there are no births on one or more days of the reproductive period, or, in other words, when one or more of the coefficients of T are made equal to 0.

In order to make clear the exact method employed, let us take the expression giving the successive births when we have—

$$G=T^1+T^2+T^3+T^4,$$

which is

$$\frac{(1-T)}{(1-2T+T^5)}.$$

In order to prepare the division conveniently, this may be written—

$$\frac{1-T+0T^2+0T^3+0T^4+0T^5}{1-2T+0T^2+0T^3+0T^4+T^5}.$$

We then proceed as follows :—

$$
\begin{array}{l}
1-2T+0T^2+0T^3+0T^4+T^5) \\
\quad 1-T+0T^2+0T^3+0T^4+0T^5\ (1+T+2T^2+4T^3+8T^4+15T^5+29T^6+56T^7\ldots \\
\quad \underline{1-2T+0T^2+0T^3+0T^4+T^5} \\
\qquad T+0T^2+0T^3+0T^4-T^5+0T^6 \\
\qquad \underline{T-2T^2+0T^3+0T^4+0T^5+T^6} \\
\qquad\quad 2T^2+0T^3+0T^4+T^5-T^6+0T^7 \\
\qquad\quad \underline{2T^2-4T^3+0T^4+0T^5+0T^6+2T^7} \\
\qquad\qquad 4T^3+0T^4-T^5-T^6-2T^7+0T^8 \\
\qquad\qquad \underline{4T^3-8T^4+0T^5+0T^6+0T^7+4T^8} \\
\qquad\qquad\quad 8T^4-T^5-T^6-2T^7-4T^8+0T^9 \\
\qquad\qquad\quad \underline{8T^4-16T^5+0T^6+0T^7+0T^8+8T^9} \\
\qquad\qquad\qquad 15T^5-T^6-2T^7-4T^8-8T^9+0T^{10} \\
\qquad\qquad\qquad \underline{15T^5-30T^6+0T^7+0T^8+0T^9+15T^{10}} \\
\qquad\qquad\qquad\quad 29T^6-2T^7-4T^8-8T^9-15T^{10}-0T^{11} \\
\qquad\qquad\qquad\quad \underline{29T^6-58T^7+0T^8+0T^9+0T^{10}+29T^{11}} \\
\qquad\qquad\qquad\qquad 56T^7-4T^8-8T^9-15T^{10}-29T^{11}+0T^{12}.
\end{array}
$$

This operation may be simplified by omitting the T's, as in what is called the method of detached coefficients, thus :—

$$
\begin{array}{l}
1-2+0+0+0+1)\ 1-1+0+0+0+0(1+1 \\
\qquad\qquad\qquad\quad \underline{1-2+0+0+0+1} \\
\qquad\qquad\qquad\qquad 1+0+0+0-1+0 \\
\qquad\qquad\qquad\qquad \underline{1-2+0+0+0+1,}
\end{array}
$$

and so on. It is not, however, necessary to carry the long division beyond the first few terms. After the coefficient of T has been obtained, the coefficient of T^2 is obtained by taking twice the coefficient of the preceding term and subtracting from it the coefficient of the fifth term back ; the coefficients of the successive terms being thus—

$$
\begin{array}{l}
\text{Cf. } T^3 = (2\times2)-0 = 4 \\
\text{Cf. } T^4 = (2\times4)-0 = 8 \\
\text{Cf. } T^5 = (2\times8)-1 = 15 \\
\text{Cf. } T^6 = (2\times15)-1 = 29 \\
\text{Cf. } T^7 = (2\times29)-2 = 56
\end{array}
$$

so that the series will be—

$$1T^0\cdot1T^1\cdot2T^2\cdot4T^3\cdot8T^4\cdot15T^5\cdot29T^6\cdot56T^7\cdot108T^8\cdot208T^9\cdot401T^{10}\cdot 773T^{11}\cdot1490T^{12}\cdot\ldots\ldots\ldots\ldots\text{etc.}$$

In the expression for—

$$G=(dT^3+dT^4+dT^5+dT^6+dT^7),$$

which is—

$$\frac{1-T}{1-T-dT^3+dT^8}$$

the successive coefficients are obtained by taking the preceding term plus d times the third term back and subtracting from this d times the eighth term back.

With the expression for irregular births, suppose we have $a=1$, $b=2$, $c=3$, $d=4$. The required series of births is then obtained by dividing $(1+0T^1+0T^2+0T^3+0T^4)$ by $(1-1T^1-2T^2-3T^3-4T^4)$, or $(1+0+0+0+0)$ by $(1-1-2-3-4)$ and the successive numbers in this case are obtained by taking the preceding term, plus twice the second term back, plus three times the third term back, plus four times the fourth term back, giving the series—

$$(1+1T^1+3T^2+8T^3+21T^4+50T^5+128T^6+323T^7+813T^8+2043T^9+5150T^{10}\ldots.)$$

The connection between the rule for obtaining the required coefficients and the form of the denominator is obvious.

By a very simple modification of the process we can obtain a series as easy to write as those already given, but in which the coefficient for any given day is the sum of the coefficient proper to the day, plus those of all preceding days from the beginning of the reproductive period.

Suppose the daily births are—

$$1T^1+3T^2+7T^3+12T^4+18T^5.$$

Then the sums of the births to each date, including those on the date considered, are given by the series :—

$$1T^1+4T^2+11T^3+23T^4+41T^5+41T^6+\ldots\ldots\ldots\ldots\ldots$$

Now

$$\begin{aligned}(1T^1+3T^2+7T^3+12T^4+18T^5)&=(1T^1+4T^2+11T^3+23T^4+41T^5+41T^6)\\&\quad-(1T^2+4T^3+11T^4+23T^5+41T^6)\\&=1(1T^1+4T^2+11T^3+23T^4+41T^5)-T(1T^1+4T^2+11T^3+23T^4+41T^5)+41T^6\\&=(1-T)(1T^1+4T^2+11T^3+23T^4+41T^5)+41T^6.\end{aligned}$$

Thus the series giving the sums of the births up to and including the successive days, is obtained from the series giving the daily births, simply by dividing by $(1-T)$.

Take the general formula—

$$G=T^1+T^2+T^3+T^4,$$

the formula for the daily births, as we have seen, is—

$$\frac{1-T}{1-2T+T^5}.$$

Dividing this by $(1-T)$ we obtain—

$$\frac{1}{1-2T+T^5}$$

and, when the division is performed we obtain a series in which, as before, we can obtain any member by taking twice the preceding member and subtracting the fifth term back, each term being, however, in this case, *equal to the sum of all the terms up to and including* the day considered.

Thus, for the formula in question we obtain a series—

$$1T^0\cdot 2T^1\cdot 4T^2\cdot 8T^3\cdot 16T^4\cdot 31T^5\cdot 60T^6\cdot 116T^7\cdot 224T^8\cdot 432T^9\cdot \ldots\ldots\ldots,$$

which sums, day by day, the members of the series—

$$1T^0\cdot 1T^1\cdot 2T^2\cdot 4T^3\cdot 8T^4\cdot 15T^5\cdot 29T^6\cdot 56T^7\cdot 108T^8\cdot 208T^9\cdot \ldots\ldots\ldots$$

previously obtained.

The same method may be followed for the case where the generation formula is irregular.

In making an actual study of the increase in population of a given species, it might be simpler to make daily counts, not of the newly born individuals, but of the total population. We, therefore, require a formula giving us the total population present each day, *including individuals of all ages.*

Suppose the generation formula is—

$$T^1+T^2+T^3+T^4,$$

in which case the series of births is—

$$1T^1+2T^2+4T^3+8T^4+15T^5+29T^6\ \ldots\ldots\ldots\ldots\ldots$$

It is evident that the individuals produced on T^1 will live, at least, on T^2, T^3, T^4, and T^5; the individuals produced on T^2 on T^3, T^4, T^5, and T^6; the individuals

produced on T^3 on T^4, T^5, T^6, and T^7, and so on. The total population will thus be—

$$\begin{array}{l}
1T^1+1T^2+1T^3+1T^4+1T^5 \\
\quad 1T^2+1T^3+1T^4+1T^5+1T^6 \\
\qquad 2T^3+2T^4+2T^5+2T^6+2T^7 \\
\qquad\quad 4T^4+4T^5+4T^6+4T^7+4T^8 \\
\hline
1T^1+2T^2+4T^3+8T^4+8T^5+7T^6+6T^7+4T^8
\end{array}$$

The complete series being thus obtained by multiplying each member by

$$(T^0+T^1+T^2+T^3+T^4) \text{ or } \frac{(T^1-T^5)}{(1-T)}$$

It is evident that if the organism continues to live after it has ceased to reproduce, this will still be valid, so that if the life is of l days, the series of births must be multiplied by—

$$\frac{(T^1-T^l)}{(1-T)}$$

to get the population series. Thus, if the formula of the births series is—

$$\frac{1-T}{1-2T+T^5}$$

the formula for the population series will be—

$$\frac{1-T^l}{1-2T+T^5}$$

The rule for finding the successive members of the series is precisely the same as before, after the term T^l has been obtained.

The series given by the formulae includes, of course, only the individuals which are capable of reproducing themselves, *i.e.*, only the females; to obtain the total number of individuals, each member of the series must be multiplied by a figure representing the ratio of total population to females, *e.g.*, by 2, if the numbers of males and females in the progeny are equal, on the average; by 4, if there are three times as many males as females, etc.

Provided we know the length of the reproductive period we can readily obtain from observations giving either the series of daily births, or the series giving the total number of individuals produced up to and including each day, the formula for individual reproduction.

It has already been shown that if the generation formula is represented by G, the series of daily births is given by the formula—

$$\frac{1}{1-G}.$$

Thus, if the series be represented by S, we have—

$$S = \frac{1}{1-G}, \text{ whence}$$

$$G = 1-\frac{1}{S}.$$

Thus, suppose the series of daily births, due to an individual reproductive period of four days, is—

$$1+1T^1+3T^2+8T^3+21T^4+\ldots\ldots\ldots\ldots ,$$

we obtain for the generation formula, by dividing the above series into 1 and subtracting the result from 1 :—

$$G=1T^1+2T^2+3T^3+4T^4.$$

III.

In the preceding section I have given a detailed explanation of the mathematical methods of dealing with the problem of overlapping generations in its various aspects. In this section I propose, with the help of these methods, to study a few hypothetical cases, in order to make clear the effect of variations in the several factors involved.

(*a*) *Effect of Variation in the length of the Pre-reproductive Period.*

This obviously regulates the *number* of generations which can occur in a given time; other things being equal.

Let the generation formula for daily births be—

$$G=T^1+T^2.$$

In which case the formula for daily births is—

$$\frac{1}{1-T-T^2},$$

and for the total births up to and including any date is, dividing by $1-T$ (see Appendix —Prop. V),

$$\frac{1}{1-2T+T^3};$$

and compare this with cases where the generation formulae are—

$$G=T^2+T^3 \text{ and}$$
$$G=T^3+T^4,$$

the formulae for daily and total births being, in the first case—

$$\frac{1}{1-T^2-T^3}, \quad \frac{1}{1-T-T^2+T^4}$$

and

$$\frac{1}{1-T^3-T^4}, \quad \frac{1}{1-T-T^3+T^5}.$$

Total Births up to and including any date.

(T^1+T^2)	(T^2+T^3)	(T^3+T^4)	Days.
1	1	1	0
2	2	1	1
4	3	2	2
7	4	3	3
12	6	3	4
20	8	4	5
33	11	6	6
54	15	7	7
88	20	8	8
143	27	11	9
232	36	14	10
376	48	16	11
609	64	20	12
986	85	26	13
1,596	113	31	14

Since the generations succeed each other more rapidly, the phenomenon of overlapping will also go on much faster as the length of the pre-reproductive period

decreases. Thus, the number of generations that co-exist on day 40 is 21 when the generation formula is T^1+T^2; 7 when it is T^2+T^3; and only 4 when it is T^3+T^4.

Since the formulae T^2+T^3 and T^3+T^4 can be written $T^2(1+T)$ and $T^3(1+T)$, the series of births for the nth generation will be $T^{2n}(1+T)^n$ and $T^{3n}(1+T)^n$. The form of the births curves will thus be identical in all three cases.

(b) Effect of Variation in the Length of the Reproductive Period.

Take the generation formulae (T^1+T^2), $(T^1+T^2+T^3)$ and $(T^1+T^2+T^3+T^4)$.

The total births up to and including the successive dates in these three cases are as follows :—

Day.	T^1+T^2	$T^1+T^2+T^3$	$T^1+T^2+T^3+T^4$
0	1	1	1
1	2	2	2
2	4	4	4
3	7	8	8
4	12	15	16
5	20	28	31
6	33	52	60
7	54	96	116
8	88	177	224
9	143	326	432
10	232	600	833
11	376	1,104	1,606
12	609	2,031	3,096
13	986	3,736	5,968
14	1,596	6,872	11,504
Ratios	4·305		1·674

In this case the successive generations will begin at the same time but they will end later and later in the second and third cases studied, as compared with the first. Thus, the dates on which the first five generations begin and end in the three cases are as follows :—

Day.	T^1+T^2		$T^1+T^2+T^3$		$T^1+T^2+T^3+T^4$	
	Beginning.	End.	Beginning.	End.	Beginning.	End.
1	1	2	1	3	1	4
2	2	4	2	6	2	8
3	3	6	3	9	3	12
4	4	8	4	12	4	16
5	5	10	5	15	5	20

Finally, the form of the births curves for the successive generations will differ more and more from generation to generation. For the first generation the coefficients (*i.e.*, in this case the numbers of births) in the first case are—

1.				1		1			
2.			1		2		1		
3.		1		3		3		1	
4.	1		4		6		4		1

In the second case they are—

1.				1	1	1			
2.			1	2	3	2	1		
3.		1	3	6	7	6	3	1	
4.	1	4	10	16	19	16	10	4	1 ;

and in the third case they are—

1.					1	1	1	1					
2.			1	2	3	4	3	2	1				
3.		1	3	6	10	12	12	10	6	3	1		
4.	1	4	10	20	31	40	44	40	31	20	10	4	1

(*c*) *Effect of the Variation in the Number of Offspring Produced Each Day.*

An increase in the number of offspring produced each day will obviously produce a marked acceleration in the rate of increase of the species.

Let us take our formula T^3+T^4 and suppose that two eggs are produced each day instead of one. The generation formula then will be—

$$\frac{1}{1-2T^3-2T^4}$$

and again, dividing by $1-T$, the total births to date are—

$$\frac{1}{1-T-2T^3+2T^5}.$$

The total births now, as compared with those when only one offspring is produced per diem, are therefore :—

Day.	T^3+T^4	$2(T^3+T^4)$
0	1	1
1	1	1
2	1	1
3	2	3
4	3	5
5	3	5
6	4	9
7	6	17
8	7	21
9	8	29
10	11	53
11	14	77
12	16	101
13	20	165
14	26	261

It is interesting to note that the doubling of the number of progeny produced per diem does not compensate for the loss of two days in the reproductive period (*cf.* T^1+T^2), though it more than compensates for the loss of one day.

(*d*) *Effect of Variation in Daily Egg Production within the same Reproductive Period, the Total Egg Production Remaining Constant.*

Suppose that the total number of eggs produced is four, as in the second of the last two cases studied, but that in one case the generation formula is either—

$$1T^3+3T^4 \text{ or } 3T^3+1T^4.$$

The formulae for the total births to date are—

$$\frac{1}{(1-T^3-3T^4)(1-T)} \quad \text{and} \quad \frac{1}{(1-3T^3-T^4)(1-T)}$$

or

$$\frac{1}{1-T-T^3-2T^4+3T^5} \quad \text{and} \quad \frac{1}{1-T-3T^3+2T^4+T^5}$$

The total births in this case are :—

Day.	$1T^3+3T^4$	$3T^3+1T^4$
0	1	1
1	1	1
2	1	1
3	2	4
4	5	5
5	5	5
6	6	14
7	12	20
8	21	21
9	22	48
10	31	75
11	58	84
12	86	166
13	98	274
14	152	328

It will be noted that the total births curves are quite different in these two cases and differ also from that which we get when two eggs are produced daily for two days. The displacement of one egg to the first day of reproduction accelerates the rise of the population ; the displacement of one egg to the second day of reproduction retards it ; though the total egg production remains constant.

(e) Comparison of Curves for Daily Birth Rate, and Daily Surviving Population, including Individuals of All Ages.

In making an actual study of the increase of an insect population it will often be difficult to distinguish individuals born on a given day from the slightly older individuals born on the preceding day. The easiest method of procedure would, therefore, be to count the total population, including individuals of all ages, every day. As has already been shown, the formula for the daily populations when the life is l days is as simple as the birth formula.

In order to give an idea of the order of the difference between the birth series and the population series, let us take the case of the generation formula—

$$G=T^1+T^2+T^3+T^4 ;$$

and suppose the life is five days, or, in other words, that the individual dies after it has finished reproducing.

The births are therefore—

$$\frac{1-T}{1-2T+T^5},$$

and the population is (see Appendix, Prop. II)—

$$\frac{1-T^5}{1-2T+T^5}.$$

The curves given by these two formulae are :—

Day.	Births.	Population.
0	1	1
1	1	2
2	2	4
3	4	8
4	8	16
5	16	30
6	31	58
7	60	112
8	116	216
9	224	416
10	432	802
11	833	1,546
12	1,606	2,980
13	3,096	5,744
14	5,968	11,072
15	11,504	21,342

APPENDIX.

Problems of Simple Propagation whose Solution may be facilitated by the use of Objective Symbols.

By H. E. Soper,

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The problem of finding the resultant at any time, from given independent incoming births, or outgoing, *i.e.*, destroyed, births of the operation of a given law of reproduction and the converse problems of how to find the independent birth happenings, knowing the resultant births and the law, and how to find the law knowing the independent birth happenings and resultant births, and many such problems, are susceptible of analysis by a process, akin to that known as " generating functions " (akin also to chemical formulation), but which is more aptly described as one that employs objective symbols to indicate and array the differing characters of the things enumerated.

In the present instance we enumerate " events " ; and the " time of occurrence " is the characteristic that we desire to set against any event. Let then T be the symbol, whose power or index has the duty of indicating the number of units of time (which unit we shall call a day for convenience although any other period may be chosen), from any zero time, at which the event happens. Hence T^0 (or 1), T^1 (or T), T^2, ... T^t, ... indicate zero time and times 1, 2, ... t, ... days after zero and an array or formula as,

$$F_0=2+5T+11T^2+25T^3+\dots, \qquad \dots \quad \dots \quad \dots \quad (i)$$

will be read as " 2 events at zero time, 5 events one day after, 11 events two days after, 25 events three days after zero ... ."

Suppose the event is a birth and suppose each event gives rise to other like events, that is births, at known intervals, then the law of reproduction can also be expressed in symbols and, for instance, the law,

$$G=5T^3+10T^5+3T^8, \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (ii)$$

would indicate 5 births 3 days after, 10 births 5 days after, and 3 births 8 days after zero, which can be the birth of the reproducing organism.

In this case it will be clear that if F_0 stand for a births formula as (*i*) and G for a generation formula as (*ii*), then

$$F^1 = F_0 \times G \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (iii)$$

will formulate, in the time symbol T, the births F_1 in the first generation arising from the original births F_0.

Here it may be pointed out that T is an objective symbol only, without the quantitative connotation of such a symbol as t in algebra, and that other large letters as F and G stand for arrays of the symbol T such as (*i*) or (*ii*). We interpret $11T^2$ in statistics in much the same way as we should interpret $11H^2$ in chemistry, but in statistics the convention leads to a useful calculus, based upon such algebraic renderings as (*iii*).

The following elementary propositions may now be enunciated.

Proposition I.—*The independent or original incoming births being* F_0 *and the generation law being* G *to find the births in the first and each succeeding generation and the total births.*

The original births are	F_0.
The 1st generations births are	F_0G.
The 2nd ,, ,, ,, ...	F_0G^2.
The r-1th ,, ,, ,, ...	F_0G^{r-1}.
The total births to the r-1th generation are ...	$F_0 \dfrac{1-G^r}{1-G}$.
The total births to unlimited generations are ...	$\dfrac{F_0}{1-G}$ *.

Proposition II.—*To find the population under these conditions when each birth survives* s *days or unit intervals.*

A birth at zero time gives rise to a population 1 in the succeeding interval and 1 in each succeeding interval to s intervals. This succession may be represented by

$$1+T+T^2+ \ldots +T^{s-1} = \frac{1-T^s}{1-T}.$$

Hence from births F formulated as occurring at successive *instants of time* 0 1 2 ...... there results a population in the succeeding *intervals of time*,† which we may call the 0 1 2 ... intervals, formulated as,

$$F\frac{1-T^s}{1-T}$$

Instants at which births occur	T^0	T^1	T^2
Intervals in which population is enumerated	T^0	T^1	T^2

Proposition III.—*To find the independent incoming births* F_0 *that must be postulated to give rise to the observed total births* F *under the known generation law* G.

Since, by Proposition I, $F = \dfrac{F_0}{1-G}$,

it follows that, $F_0 = F(1-G)$.

* We say that G^r is negligible when $r=\infty$, not because $G < 1$, but because we do not concern ourselves with the exact enumeration of events at infinite time.

† It would perhaps have accorded better with our common conceptions had populations been put at instants and births in intervening intervals of time.

Proposition IV.—*To find the generation law, given the independent incoming or originating births* F_0 *and the observed total births* F.

Since, by Proposition I, $F = \dfrac{F_0}{1-G}$,

it follows that, $G = 1 - \dfrac{F_0}{F}$.

Proposition V.—*A series of events being expressed as an array* F *in the symbol* T, *to find the slope of the curve and its inflexion and to find the successive sums or totals, these also being expressed in array form.*

The slope or backward first difference is $(1-T)F$.

The inflexion or backward 2nd difference is $(1-T)^2F$.

The sum to (and including) the instant is $\dfrac{F}{1-T}$.

The second, third, etc., sums are $\dfrac{F}{(1-T)^2}$, $\dfrac{F}{(1-T)^3}$, etc.

The succeeding items follow from the first, and the first is obvious since if

$$F = a + bT + cT^2 + \ldots\ldots$$

then

$$(1-T)F = a + (b-a)T + (c-b)T^2 + \ldots\ldots$$

Many other propositions could be stated, but the process is so elementary that the student will be able, with the help of the above examples and using similar algebraical renditions and transformations, to evolve many desired results. Since there are sometimes several ways of expressing an array the following examples are given in illustration of the methods that can be impressed into service.

Example 1.—An organism produces d births each day for k days commencing with the hth day from its birth. What are (*a*) the births of each generation from one primary birth and what (*b*) the births of all generations? What is (*c*) the slope of the births curve and (*d*) the inflexion and (*e*) the totality of births to any date and (*f*) the births in successive weeks? What (*g*) is the population, if the life is l days? Take *e.g.*, $d=2$, $h=3$, $k=5$, $l=6$.

The digits 2, 3, 5, 6, in what follows, are inserted for d, h, k and l, and are easily changed for others at will.

Here $F_0 = 1$ and $G = 2T^3 + 2T^4 + 2T^5 + 2T^6 + 2T^7$,

which it will much simplify the work to write $G = \dfrac{2T^3 - 2T^8}{1-T}$.

The 1st, 2nd, 3rd, ..., generations are here G, G^2, G^3, ... and since these are a little awkward to develop in the first form of G it will be easier to take the second form and regard the denominators $\dfrac{1}{1-T}$, $\dfrac{1}{(1-T)^2}$, $\dfrac{1}{(1-T)^3}$, etc., as asking us to take the 1st, 2nd, 3rd, etc., *sums* of $(2T^3-2T^8)$, $(2T^3-2T^8)^2$, $(2T^3-2T^8)^3$, etc. (see Proposition V). For example, the *third generation* is $\dfrac{(2T^3-2T^8)^3}{(1-T)^3}$ and so is the third sum of $(2T^3-2T^8)^3$, and the work is, detaching the coefficients—

Index of T	0...9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
$(2T^3-2T^8)^3=$	8					-24					24					-8
1st sum	8	8	8	8	8	-16	-16	-16	-16	-16	8	8	8	8	8	
2nd sum	8	16	24	32	40	24	8	-8	-24	-40	-32	-24	-16	-8		
3rd sum (G^3)	8	24	48	80	120	144	152	144	120	80	48	24	8		...	(*a*)

The *births from all generations* are

$$\frac{F_0}{1-G}=\frac{1-T}{1-T-2T^3+2T^8},$$

where again, much to our benefit, we use the second form of G. The expansion of this by ordinary division begins with

$$1+2T^3+$$

and this needs only to be taken as far as T, the highest power of T in the numerator. Thereafter each term must be the term ante multiplied by T plus the third term ante multiplied by $2T^3$ minus the eighth term ante multiplied by $2T^8$, for in no other way can the numerator $1-T$ be got by multiplying the answer by the denominator $1-T-2T^3+2T^8$, a result that is manifestly entailed.

Hence we can write down the *births from all generations* in the successive units of time (including the original birth) as,

1 0 0 2 2 2 6 10 12 24 44 64 108 192 ... (*b*)

the last figure 192 being got as once 108+twice 44—twice 2, the figures —2 2 and 1 being put at the right spacings on a card which is slipped along.

The *slope* of the births curve is therefore,

1 -1 0 2 0 0 4 4 2 12 20 20 44 40 ... (*c*)

The *inflexion* (by taking differences again) is,

1 -2 1 2 -2 0 4 0 -2 10 8 0 24 -4 ... (*d*)

The *sum* of births to and including date (by adding) is,

1 1 1 3 5 7 13 23 35 59 103 167 275 467 ... (*e*)

From this by taking differences at 7 days intervals we get the *births in successive weeks* as,

13 454 .... (*f*)

The *population* is $\frac{1-T^6}{1-T}\times\frac{1-T}{1-T-2T^3+2T^8}=\frac{1-T^6}{1-T-2T^3+2T^8};$

hence it obeys the same succession rule as births, but now instead of subtracting a T we must subtract a T^6, *i.e.*, deduct *one* when we calculate the seventh figure instead of when we calculate the second figure. The result is (using the same card),

1 1 1 3 5 7 12 22 34 56 98 160 262 444 ... (*g*)

Example 2.—Inverse problems. The derivation of the independent incoming births by the formula of Proposition III will present no difficulty and it may be observed here that the same formula will, by the ordinary algebraic convention of signs, give, as an alternative result, the independent *outgoing* or *destroyed* births, due to any agencies that may be operating, these destroyed births being thus easy to disentangle from their rather complicated consequences.

The second inverse problem, that of deducing the generation law from the independent births and the total observed births, needs a division of the series F_0 by the series F and this can be carried out in the manner described in Example 1, that is by getting each new quotient figure from the old ones without commitments to paper. As an example, always detaching the numbers from the understood symbols, 1, T, T^2 ....,

If F_0 =	1	2	3	4	5	4	3	2	1	2	3	4	5	4
and F =	1	2	3	5	10	18	34	62	111	203	373	683	1247	2271

then

$1-G=\frac{F_0}{F}=$	1	0	0	-1	-3	-5	-7	-6	-4	-2	0	0	0	0
$\therefore\ G=$	0	0	0	1	3	5	7	6	4	2				

If from the assumed wavy independent inflow F_0 are observed the daily births F, then to obtain this result we must postulate that each new birth produces 28 births, commencing 1 birth on the third day after the birth day, then 3 5 7 6 4 2 births on the succeeding six days.

The figure -2 (third line) was got as 2 (top line supra) $-(203)\times(1)$ (third line) $-(111)\times(0)-(62)\times(0)-(34)\times(-1)-(18)\times(-3)-(10)\times(-5)-(5)\times(-7)-(3)\times(-6)-(2)\times(-4)$. This multiplication of backward going figures by forward going figures is done quickly on a calculating machine, and if the series are long it is as well to reverse the backward taken series on a slip of paper which is pushed along.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st October and 31st December, 1930, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Mr. W. Allan :—6 Culicidae, 6 *Glossina*, 56 Coleoptera, 25 Rhynchota, the wings of 4 Acrididae, and 5 Orthoptera ; from Northern Rhodesia.

Mr. T. J. Anderson, Government Entomologist :—84 Lepidoptera ; from Kenya Colony.

Mr. E. Ballard, Chief Plant Pathologist :—500 Parasitic Hymenoptera ; from Egypt.

Mr. P. J. Barraud, Medical Entomologist :—89 Diptera ; from the Punjab, India.

Mr. G. E. Bodkin, Government Entomologist :—4 Culicidae, 4 Tabanidae, 372 other Diptera, 1,135 Coleoptera, 56 Parasitic Hymenoptera, 281 other Hymenoptera, 2 Lepidoptera, 151 Rhynchota, and 506 Orthoptera ; from Palestine.

Dr. G. Bondar :—18 Coleoptera and 7 Parasitic Hymenoptera ; from Brazil.

Mr. L. L. Buchanan :—2 Curculionidae ; from Argentina.

Dr. P. A. Buxton, London School of Tropical Medicine :—46 Culicidae, 21 Tabanidae, and 9 other Diptera ; from Sierra Leone.

Chief Entomologist, Pretoria :—10 Diptera, 472 Coleoptera, and 39 Parasitic Hymenoptera ; from South Africa.

Mr. A. H. St. Clair :—33 Orthoptera ; from Kenya Colony.

Prof. T. D. A. Cockerell :—31 Coleoptera, 72 Lepidoptera, and 2 Orthoptera ; from Siam.

Mr. W. Cook :—55 Lepidoptera and 7 larvae and 15 Millipedes ; from the Gold Coast.

Mr. G. H. Corbett, Government Entomologist :—241 Diptera, 255 Coleoptera, 1,100 Parasitic Hymenoptera, 50 Formicidae, 137 Lepidoptera, 117 Isoptera, 50 Thysanoptera, 2 species of Coccidae, 2 species of Aphidae, 42 other Rhynchota, and 72 Orthoptera ; from Malaya.

Coryndon Memorial Museum, Nairobi :—73 Coleoptera and 1,016 Rhynchota ; from Kenya Colony.

Dr. J. Davidson :—5,000 Chalcididae and Galls and 9 species of Coccidae ; from South Australia.

Mr. D. D'Emmerez de Charmoy :—3 species of Aphidae ; from Mauritius.

Mr. P. R. Dupont :—1 species of Coccidae and 1 species of Aphidae ; from the Seychelles.

Brig.-Gen. W. H. Evans :—25 Rhynchota, 150 Orthoptera, and 107 Odonata ; from Baluchistan, India.

Mr. S. Fedorov :—68 Coleoptera and 9 Orthoptera ; from Crimea.

Mr. J. C. M. Gardner, Systematic Entomologist :—56 Coleoptera, 39 Parasitic Hymenoptera, and 12 Lepidoptera ; from the United Provinces, India.

Prof. B. A. R. Gater :—14 Hippoboscidae ; from Singapore.

Mr. E. G. Gibbins :—105 *Phlebotomus*, 161 Ticks, and 20 Mites ; from Uganda.

Mr. P. v. d. Goot :—27 Lepidoptera ; from Java.

Miss L. F. Graham :—8 Parasitic Hymenoptera and 8 cocoons ; from Australia.

Mr. W. Greenwood :—2 Coleoptera, 4 Parasitic Hymenoptera, 70 Lepidoptera, and 5 Rhynchota ; from Fiji.

Mr. W. B. Gurney, Government Entomologist :—20 Coleoptera and 9 larvae ; from New South Wales, Australia.

Mr. G. L. R. Hancock, Assistant Entomologist :—11 Diptera, 3 Coleoptera, 26 Parasitic Hymenoptera, 67 Lepidoptera, and 15 Rhynchota ; from Uganda.

Mr. G. H. Hardy :—24 Diptera ; from Queensland, Australia.

Mr. E. Hargreaves, Government Entomologist :—8 Culicidae, 2 Tabanidae, 175 other Diptera and 14 pupa cases, 88 Coleoptera, 99 Parasitic Hymenoptera, 38 other Hymenoptera, 129 Lepidoptera, 250 Thysanoptera, 6 species of Coccidae,

1 species of Aleurodidae, 147 other Rhynchota, 119 Orthoptera, 7 Dermaptera, 14 Trichoptera, 510 Mites, 2 Spiders, and 30 Parasitic Worms; from Sierra Leone.

Mr. H. HOCKINGS :—5 Coleoptera and 2 larvae; from Queensland, Australia.

Mr. W. E. HOFFMANN :—184 Orthoptera; from China.

Mr. S. HUMPHRIES :—60 Scolytidae; from Surrey.

Dr. J. C. HUTSON, Government Entomologist :—185 Parasitic Hymenoptera; from Ceylon.

Mr. C. A. ISAAKIDES :—2 Parasitic Hymenoptera; from Greece.

Dr. H. C. JAMES, Assistant Entomologist :—12 Diptera, 25 Coleoptera, 66 Parasitic Hymenoptera, and 3 Chrysopidae; from Kenya Colony.

Mr. JONES :—5 Rhynchota and 12 Orthoptera; from Simla, India.

Dr. K. KUNHI KANNAN, Entomologist :—129 Coleoptera; from Mysore, India.

Dr. KRUGER :—15 Orthoptera; from North Africa.

Mr. O. B. LEAN, Assistant Entomologist :—6 Orthoptera; from Southern Nigeria.

Dr. S. LEEFMANS :—80 Parasitic Hymenoptera; from Java.

Mr. R. A. LEVER :—6 Culicidae, 6 Tabanidae, 33 other Diptera, 116 Coleoptera, 45 Hymenoptera, 7 Lepidoptera, 2 Isoptera, 4 Cicadid skins, 84 other Rhynchota and 3 nymphs, 47 Orthoptera, 2 Dermaptera, 2 Planipennia, and 13 Ticks; from the British West Indies.

Mr. J. W. MCHARDY, Medical Entomologist :—5 Ticks; from Tanganyika Territory.

Mr. A. J. MAAS :—4 Parasitic Hymenoptera; from France.

Mr. N. C. E. MILLER, Assistant Entomologist :—51 Coleoptera; from Malaya.

Mr. J. MIMEUR :—20 Parasitic Hymenoptera; from Morocco.

Mr. H. M. MORRIS, Government Entomologist :—50 Diptera, 197 Coleoptera, 10 Chalcididae, 14 Lepidoptera, 25 Rhynchota, and 3 Ascalaphidae; from Cyprus.

Mr. C. F. W. MUESEBECK :—118 Parasitic Hymenoptera; from various localities.

Mr. J. MUGGERIDGE :—6 Coleoptera; from New Zealand.

Mr. R. W. PAINE :—8 Diptera, 36 Coleoptera, 100 Parasitic Hymenoptera, and 50 Mites; from Java.

Dr. H. L. PARKER :—2 Braconidae; from France.

Mr. W. H. PATTERSON : 317 packets of Aleurodidae; from the Gold Coast.

Mr. A. W. J. POMEROY, Medical Entomologist :—36 Culicidae; from the Gold Coast.

Mr. O. W. RICHARDS :—29 Parasitic Hymenoptera; from England.

Mr. A. H. RITCHIE, Government Entomologist :—6 Coleoptera, 3 Rhynchota, and 3 Orthoptera; from Tanganyika Territory.

Dr. A. ROMAN :—124 Parasitic Hymenoptera; from Germany.

Dr. H. SCHOUTEDEN :—5 Rhynchota; from the Belgian Congo.

Prof. F. SILVESTRI :—3 Braconidae; from Italy.

Mr. G. W. STELFOX :—48 Parasitic Hymenoptera; from Ireland.

Prof. C. STRICKLAND :—1 Reduviid; from Calcutta, India.

Mr. SUREYA BEY :—6 Culicidae, 31 other Diptera, 434 Coleoptera, 60 Parasitic Hymenoptera, 18 other Hymenoptera, 1,444 Lepidoptera, 40 Lepidopterous early stages, 1 species of Coccidae, 6 species of Aphidae, 200 other Rhynchota, and 1,024 Orthoptera; from Turkey.

Mr. T. H. C. TAYLOR :—13 Lepidoptera; from Fiji.

Dr. I. TRÄGÅRDH :—2 Diptera; from Sweden.

Prof. L. B. UICHANCO :—18 Orthoptera; from the Philippine Islands.

Mr. G. C. ULLYETT :—14 Diptera, 50 Parasitic Hymenoptera, and a tube of Nematodes; from South Africa.

Mr. P. VAYSSIÈRE :—1 Ichneumonid; from France.

Mr. J. VAN DER VECHT :—7 Parasitic Hymenoptera; from Java.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—59 Coleoptera; from the Sudan.

Dr. F. ZACHER :—24 Coleoptera; from various localities.

Mr. R. H. VAN ZWALUWENBERG :—2 Coleoptera; from Honolulu.

AN EXPERIMENT ON THE FEEDING-HABITS OF *GLOSSINA SWYNNERTONI* (DIPT.).

By C. H. N. Jackson, Ph.D., M.Sc.,

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I. Introduction.

During July and part of August 1929 an experiment was carried out at Sambala (Western Kondoa), Tanganyika Territory, designed to show that: (i) Hungrier flies marked in *Berlinia-Brachystegia* woodland left that type for the supposed feeding-grounds ("female centres") earlier than repleter flies; (ii) conversely, repleter flies remained within the woodland longer than hungrier flies; (iii) hungrier flies in the supposed feeding-grounds remained in them for the first few days; and lastly (iv) repleter flies in these situations returned to the *Berlinia-Brachystegia* woodland to remain there until later.

It was considered that a positive result would prove that the *Berlinia-Brachystegia* woodland, where flies were repleter, was the home of the fly; and that the "female centres," where flies were hungrier, were feeding-grounds to which they proceeded at the onset of hunger in the home.

In the presentation of the results of the experiment (Bull. Ent. Res. xxi, Dec. 1930, pp. 491–527), the proportions of hungrier and repleter flies were compared in respect of the numbers recaptured in the first three days and afterwards in "female centres." It was shown that the numbers of hungrier flies marked in *Berlinia-Brachystegia* woodland and recaptured in "female centres" during the first three days after marking bore a higher proportion to the numbers recaptured there afterwards than did the corresponding numbers of originally repleter flies recaptured in "female centres" to the numbers of those flies recaptured afterwards therein.

That is to say, a positive and statistically significant result was obtained under the heads (i) and (iv) above; under heads (ii) and (iii) the results tended to be positive, but were statistically insignificant. The total numbers were not very large, nor were the levels of significance very high.

In view of the somewhat unsatisfactory result of this experiment, it was intended to repeat it on the Zoologist's return from leave in the belt of *Glossina morsitans* in Eastern Kondoa. This was prevented by his transference to the *G. swynnertoni* fly-belt in Shinyanga.

As, however, the anatomy of this fly-belt showed on investigation a condition essentially similar to that obtaining in areas inhabited by *G. morsitans*, it was considered that a positive result from such an experiment as the above would be of additional interest as corroborating the feeding-ground concept as applied to *G. morsitans*, and at the same time proving that *G. swynnertoni* was a species of similar habits.

II. Area chosen for the Experiment.

The hungry-fly area selected as the hypothetical feeding-ground included a length of road, two-thirds of a mile long, used by pedestrians but closed to motor traffic, and bordered on its west side by a clearing from 150 to 300 yards in width. This clearing previously had been burned to a uniform distance of 100 yards west of the road, as part of the measures connected with experimental reclamation against the fly. On its east side the road was bordered by a clearing 100 yards or more in width; this clearing was unburned. The supposed feeding-ground was taken to be the road

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together with the burned portion of the clearing on its west side; on both the road and the burned ground young grass was shooting. Fly was abundant on the road, and nearly as abundant on the burned ground.

The supposed home of the fly, to which it was believed to return for the digestion of engorged blood and for breeding purposes, was represented by a transect marked out about 200 yards inside the bush bordering the clearing and opposite the chosen strip of road. The bush was fairly typical of that found throughout the area, important constituents being *Commiphora fischeri*, *C. schimperi*, *C. pilosa* and *C. ugogensis*, *Acacia spirocarpa*, *A. rovumae*, *A. benthami*, *Combretum apiculatum*, *C. longispicatum*, *C. parvifolium*, *Lannea humilis*, *Ormocarpum trichocarpum*, *Dalbergia melanoxylon*, *Strychnos heterodoxa*, *Strophanthus eminii*, and *Grewia*.

The unburned portion of the clearing, dividing the "feeding-ground" from the "home," was taken to be a transition area from the zoological point of view.

III. Animals present.

Species of antelope present within the area included roan, greater kudu, impala, duiker, and dikdik. Giraffe and warthog were common; lion, jackal, and hyaena frequent. Hares, *Cercopithecus* monkeys, mongooses, guinea-fowl, francolins, and sand-grouse, represented the smaller animals. On the road there was considerable traffic of man and sometimes of cattle, proceeding to and from Shinyanga and Seke.

The road and burnt ground were much frequented by the animals listed above, with the exception of the kudu, which usually were seen in the bush, where also the other species occurred.

IV. Period and Nature of the Experiment.

Flies were marked from 17th July to 27th August inclusive; during this period marking was omitted on 9 days. Recapturing of flies continued up to 30th August, when the experiment was concluded.

The planning of the experiment was guided by the consideration that heads (i) and (ii) of the experiment described above were capable in themselves of proving the point at issue; and that heads (iii) and (iv) were less important and also redundant. Attention therefore was concentrated on the first two heads alone; flies were marked in the bush only, in the first instance, and re-marked on recapture both in the bush and in the open.

Flies retaken in transition zones are not included in the figures which follow.

V. Method.

Marking of flies in the bush took about an hour and was carried out from about 4.0 to 5.0 p.m. About 35 flies were marked in the bush daily, and, as at Sambala, differential marking was employed to show date and state of hunger; since marking took place in the first instance in the bush only, it was not necessary to indicate the locality in which flies were marked.

The marking and recapturing in the bush were preceded and followed by recapturing along the road, on the burned ground and in the transition areas. During the morning, two natives were sent regularly to collect, kill, and bring in marked flies from the road only. (This diminished the number of individual flies caught several times, but increased the total number of recaptures.)

Precautions were taken to avoid carrying flies out from the bush to the open at the end of marking, and into the bush from the open at the start. On approaching the bush, the party (consisting of the Zoologist and three natives) collected and killed all unmarked flies found along the path in the transition area, halts being made to ensure that none followed in. Marked flies were re-marked, and if they followed into

the bush, note of the fact was made. The transition at this point was about 200 yards in width. Marking of flies ceased about 150 yards before the end of the bush was reached, and any freshly marked flies which followed beyond a point about 100 yards inside the edge of the bush were re-marked to indicate that they had done so. None of these flies are included in the figures given below. Marking and recording of recaptures were done by the Zoologist, other recording by dictation to a native. Re-marking was carried out on the clock system previously described in the account of the experiment at Sambala.

VI. Numbers of Flies marked and recaptured.

The total numbers marked in the bush were :—

Males (I)*	Males (II–III)	Males (IV)	Males (V–VI)	Females	Total males	Total flies
64	304	431	229	110	1,028	1,138

* For an explanation of these grades see page 178.

There were 533 recaptures relevant to the point at issue, of which 340 were in feeding-grounds and 193 in the home. In addition, there were 49 recaptures in transition areas, and a number of other recaptures were rejected on the ground that their markings were obscure or that there was some other objection ; 17 females were recaptured, of which 2 only were in the home. Of *G. pallidipes* 6 males and 2 females were marked ; these are not included in the figures given above, and none were retaken.

Of the recaptured flies, 102 were caught three or more times, of which 14 were caught four times, 3 five times, and 2 six times ; 201 flies were killed (instead of being re-marked and released).

It is of interest to note that 2 male flies in stage V (hungry) and 1 in stage IV (slightly hungry), all marked the same day in the bush, were taken on the road in the evening at a point some considerable distance from the point of emergence from the bush. It is probable that these had not followed the party out, but had emerged independently from the bush. They are not included in the recaptures above.

The total flies from a small number of reconnaissances along the road were :—

Males (I)	Males (II–III)	Males (IV)	Males (V–VI)	Females	Total males	Total flies
1	3	34	90	108	128	236

From these figures it is apparent that flies on the road were appreciably hungrier than those in the bush. This fact was very apparent even without the taking of samples.

VII. Results of the Experiment.

These will be given first in the form in which they were presented at Sambala.

Place of marking	Place of recapture	Condition	First 3 days	Afterwards	Ratio
Home	Feeding-ground	Hungrier	131	119	1 : 0·9
		Repleter	41	69	1 : 1·7
Home	Home	Hungrier	39	53	1 : 1·3
		Repleter	71	30	1 : 0·4

These two results are evidently in harmony with the hypothesis, for in each case such a result would occur by chance less than once in 100 trials. A result agreeing with the above is obtained when the figures collected during July are taken alone.

In this case the figures will bear closer scrutiny than those obtained at Sambala, perhaps because the experiment was better planned. It is possible to separate the different hunger stages for detailed examination. These stages are: I, Gorged; III, replete (including stage II, very replete); IV, slightly hungry; V, hungry, including all females, and flies in stage VI, which have not yet had their first meal.

Taking the numbers of recaptures for the first week after marking, we have :—

1. Home to Home.

Stage	Days after ...	1	2	3	4	5	6	7
I	... ...	10	2	5	0	0	0	0
III	... ...	38	11	5	6	9	5	1
IV	... ...	19	7	5	6	8	7	5
V	... ...	5	1	2	4	2	2	1
	Total ...	72	21	17	16	19	14	7

2. Home to Feeding-ground.

Stage	Days after ...	1	2	3	4	5	6	7
I	... ...	1	0	3	2	0	0	2
III	... ...	10	15	12	10	10	5	5
IV	... ...	35	21	19	9	7	15	9
V	... ...	28	18	10	5	4	4	3
	Total ...	74	54	44	26	21	24	19

Taking the differences between the logarithms of the respective numbers in the two sets gives the proportion of numbers in the feeding-grounds to numbers in the home on successive days after marking. Thus :—

Stage	Days after ...	1	2	3	4	5	6	7
I	... ...	—1·00	—0·30	—0·22	*0·30*	(Numbers too small)		
III	... ...	—0·58	0·14	*0·38*	0·22	*0·05*	*0·00*	0·60
IV	... ...	0·27	*0·48*	*0·58*	0·18	*—0·06*	0·33	0·26
V	... ...	0·75	*1·26*	0·70	*0·10*	0·30	0·30	0·48
	Total ...	0·01	*0·41*	*0·41*	0·21	*0·04*	0·23	0·43

From the above figures it is evident that :—

1. The proportion of hungry flies in the feeding-grounds to those in the home is highest on the second day after marking.

2. The proportion of replete flies is highest in the feeding-grounds on the third day; on the first day they show a marked tendency to remain in the home.

3. The slightly hungry flies show an intermediate condition in both particulars.

4. The gorged flies, in so far as the numbers are large enough to be considered at all, show a tendency to remain in the home during the first 3 days.

5. The replete flies tend to return to the home on the 5th–6th day, the hungry flies on the 4th day, and the slightly hungry flies again are intermediate.

6. The flies as a whole tend to be in the feeding-grounds on the 2nd–3rd days, and to return to the home on the 5th day. Afterwards they begin to return to the feeding-grounds. (In the curve of the total flies the numbers are larger and the periodicity is better marked.)

The figures cannot be taken beyond the first week because they rapidly become too small, and also because the flies begin to feed and digest at different rates after this time.

VIII. Flies two or more times recaptured.

Suggestive cases bearing on the feeding-ground concept and hunger-periodicity will be considered.

H=Home. T=Transition zone. FG=Feeding-ground.

No.	Place	Stage	Days after	Remarks
10	H FG H	III IV early III	 2 3	Replete in H, slightly hungry in FG, replete in H. Suggesting a 5-day periodicity.
13	H FG H FG	V V IV V	 1 6 6	Hungry in H; goes quickly to FG. Later slightly hungry in H and, after, hungry in FG. Suggesting a 5-day periodicity.
18	H FG FG	I IV V	 3 1	Gorged in H; later slightly hungry in FG, where remains while hunger increases.
22	H FG FG FG	IV V V V	 6 1 18	Slightly hungry in H. Later hungry in FG, where remains 1 day. Later returns hungry to FG. Suggesting a 5-day periodicity.
23	H FG FG	IV IV V	 1 1	Slightly hungry in H, visits and remains 1 day in FG.
24	H H FG FG	V V V V	 1 2 1	Delaying to leave H when hungry, later visits and remains in FG.
25	H H H	I III IV	 1 1	Remaining in H during digestion.
27	H H FG	III IV V	 1 2	Remaining in H during digestion, later visiting FG.
28	H H FG	IV IV V	 2 1	As above.
30	H H FG	IV III IV	 4 1	Returning to H after feeding; later visiting FG. Suggesting a 5-day periodicity.

H= Home. T= Transition zone. FG= Feeding-ground.

No.	Place	Stage	Days after	Remarks
32	H H FG	IV IV IV late	 6 1	As above, but suggesting a 6–7-day periodicity.
34	H H FG FG	III IV IV V	 1 7 1	Remaining in H during digestion. Much later in FG, remaining there 1 day. Suggesting a periodicity *not* of 5 days.
35	H H H FG	III IV III V	 17 3 3	In H while replete or slightly hungry; in FG when hungry. Suggesting a 4–5-day periodicity.
41	H H FG FG	V V V V	 1 1 1	Female. Delaying 1 day to leave H when hungry, then visiting and remaining 1 day in FG.
44	H H FG	IV IV V	 5 6	Very suggestive of the 5-day periodicity.
46	H H H	III III IV	 1 1	Remaining in H during digestion.
50	H H FG	IV IV IV	 5 5	Suggesting the 5-day periodicity.
52	H FG H	V V I	 1 17	Hungry in H, proceeding at once to FG. Later gorged in H.
53	H H H	III III III	 5 1	Suggesting a 5–6-day periodicity.
85	H H FG	IV IV V	 6 3	Suggests a 6-day, periodicity. In FG when hungry.
87	H FG FG	V V V	 1 1	Hungry in H, proceeding to FG and remaining 1 day.
90	H FG FG	IV IV V	 4 1	Suggests a 4-day periodicity.
91	H H FG	I III V	 1 2	Fly remaining in H during digestion, in FG when hungry.
92	H T FG	IV IV late IV	 5 6	Suggests a 5–6-day periodicity.
94	H FG T	V V IV	 1 3	Suggests a 4–5-day periodicity. When hungry in H proceeds to FG.

H = Home. T = Transition zone. FG = Feeding-ground.

No.	Place	Stage	Days after	Remarks
97	H	IV		Suggests a 5–6-day periodicity. Proceeds to FG at onset of hunger.
	T	IV	5	
	FG	IV	1	
98	H	I		Remaining in H during digestion.
	H	III	1	
	H	IV	1	
99	H	IV		Suggests a 5-day periodicity.
	T	III	4	
	T	III late	1	
100	H	III		Suggests a 5-day periodicity.
	H	III	5	
	T	IV early	1	
102	H	V		Suggests a 6–7-day periodicity.
	FG	V	6	
	FG	V	1	
105	H	IV		Suggests a 5–6-day periodicity. Proceeds to FG at onset of hunger.
	T	IV	5	
	FG	IV	1	

The above cases suggest that the fly feeds about every fifth day, and in general are in harmony with the feeding-ground concept.

On the other hand, there are a few cases in which gorged flies became hungry or slightly hungry in one day only, and others where flies noted as being hungry one day were recaptured, apparently slightly hungry only, on the day following. Similar cases were recorded at Sambala, but they are believed to be exceptional, or in some instances perhaps wrongly diagnosed.

A few flies kept in captivity showed considerable variation in the rate of onset of hunger, but most of them required 2 or 3 days to reach stage V after engorgement. This subject requires investigation, but there is some reason to believe that these flies became hungrier somewhat more quickly than they would have done in the field.

It may be mentioned that a small series of dissections, carried out at Kikori by Mr. W. H. Potts, Senior Entomologist, and the Zoologist in November 1929, gave support to the view that the hunger-staging used in the field could be correlated fairly well with the internal condition of the flies.

IX. Conclusions.

The experiment has shown, at least as concerning the area and the period included by it, that:

1. Hungrier flies precede repleter flies from the bush to the open glade, which therefore may be considered to be their feeding-ground.

2. Flies visit the feeding-ground once about every fifth day.

3. Examination of the records of flies several times recaptured suggests that five days is about the time taken by flies to complete their hunger cycle.

TWO NEW SPECIES OF *URANOTAENIA* (CULICIDAE) FROM NIGERIA, WITH NOTES ON THE GENUS IN THE ETHIOPIAN REGION.*

By Cornelius B. Philip.

During the course of certain investigations, the writer had occasion to collect a considerable number of mosquitoes in Nigeria, particularly in the vicinity of Lagos. Several species of *Uranotaenia* were represented in many of the collections. In view of the difficulties experienced in identifying certain specimens, opportunity was taken during a recent visit to the British Museum (Natural History) to study the African *Uranotaenia* in the collections there. Subsequent to the publication by Edwards in 1912 of the last generic treatment and key for the separation of the species, several additional species have been added to the list from the Ethiopian region, and more materials have accumulated, thus facilitating further study and permitting a reconsideration of certain specific assignments.

Moreover, of a total of eight species of *Uranotaenia* taken in and about Lagos by the writer, two have proved to be new, while another series of specimens represents a species of which only the type female had previously been available in the British Museum collections. Many specimens were obtained in adult collections, and others were reared from larval samples. Adults were usually captured by means of a " sucker " adapted from a type used in malarial investigations by Dr. M. A. Barber and Dr. T. B. Hayne of the West African Yellow Fever Commission. The modification consists of a glass " mosquito-catching tube " 5 inches in length with an outside diameter of 1·25 inches. One end is continuous with an inverted glass cone about 0·75 inch deep, having an opening at the apex 0·25 inch in diameter. Into the other or open end of the catching chamber a cork is fitted, through which runs a short piece of glass tubing connected to a flexible rubber tube of arm's length. The latter is stiff enough to minimise kinking while in use.

In operation, the free end of the rubber tube is held in the mouth and captures are effected by holding the opening of the " catcher " near a resting or flying insect, when sharp inhalation through the rubber tube will " suck " the insect into the catching chamber. A wire gauze guard covered by softer cloth netting, to break the impact of the insect during capture, is fitted over the inside of the cork stopper to prevent mosquitoes from being drawn back into the mouth. Paraffin is filled in around the cone on the inside to a level with the opening, thus allowing the captive insects to be quickly blown into another tube where they can be chloroformed before injury and rubbing interferes with later identification.

This catcher has been found to be particularly well adapted for obtaining adult samples from crab-holes and inaccessible places of concealment with which one has to deal in collecting mosquitoes inside native quarters, and since it has also shown itself to be extremely useful in laboratory studies involving the handling of large numbers of adult mosquitoes, it has been illustrated in Figure 1.

An especially favoured haunt of several species of *Uranotaenia*, it was observed, were the crevices about the ruined fireplace of an abandoned, roofless, brick building in Ebute Metta, near Lagos. The walls were moss-covered and the old built-in oven seemed to furnish the particular type of dark, damp shelter which they preferred. This ruin was isolated in a small wood (" Botanical Gardens ") near the lagoon, but there was, nevertheless, a dense human population in the vicinity.

* The studies and observations on which this paper is based were conducted in Lagos, Nigeria with the support and under the auspices of the International Health Division of the Rockefeller Foundation.

Larva collections from crab-holes were obtained by the pump method described by Dunn (1927).

Thanks are due the officials of the British Museum, particularly Mr. Edwards, for placing at the writer's disposal facilities for studying and comparing their authentic specimens with the materials he brought from Nigeria. Mr. Edwards was very generous with suggestions and unpublished data. His previous treatment has been freely drawn upon in presenting the following key to the adults.

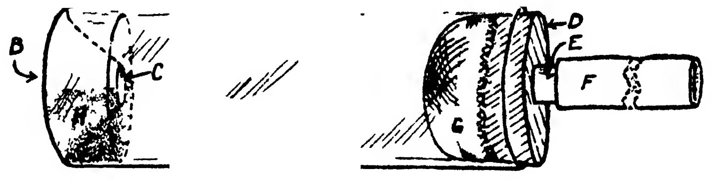

Fig 1 Adult-mosquito catcher, used in the field during collecting, or in the laboratory for sorting blood-fed specimens during cage experiments A, glass chamber, B, inverted glass cone continuous with sides of chamber, and having opening, C, at apex, D, cork through which passes short glass tube, E, F, flexible rubber tube of arm's length Cloth gauze over wire screen, G, breaks impact of insect sucked into chamber Paraffin filling, H, around inside of cone, allows insect to be quickly blown into another chamber similar to A with gauze taped over free end in place of the cork stopper, and without paraffin about the cone

Miss Evans, of the Liverpool School of Tropical Medicine, has also kindly supplied some notes and information regarding unrecorded localities for specimens represented in their collections.

The descriptive terminology of the thoracic sclerites employed below is illustrated in Figure 2.

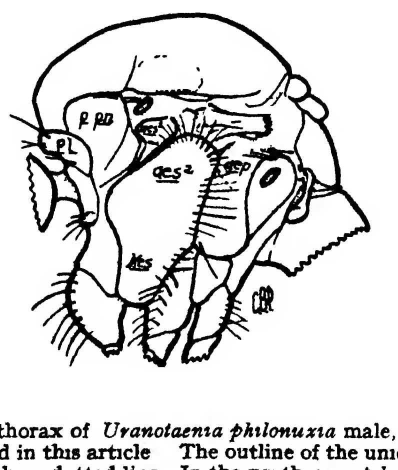

Fig 2 Lateral view of thorax of *Uranotaenia philonuxia* male, n sp, labelled to show pleural sclerites mentioned in this article The outline of the unique pre-alar scale patch in this species is indicated by a dotted line. In the prothorax, *p l*, pronotal lobes (anterior pronotum of Patton and Evans), *p pn*, posterior pronotum (proepimeron of authors); in the mesothorax, *aes*¹, anterior anepisternum, *aes*² and *kes* combined, posterior anepisternum and katepisternum (sternopleurite of Osten Sacken and others) respectively; *aep*, anepimerum (pteropleurite of authors) Scales and mesonotal bristles omitted.

Revised Key to Ethiopian Species of Uranotaenia.*

1\. Thorax with white or bluish markings composed of flat scales in front of the base of the wings; the latter with one or more of the veins clothed basally with white scales, except in *montana* (*Uranotaenia*, sens. str.) 2
Thorax without any flat scales in the pre-alar areas; wings usually without any white scales (*Pseudoficalbia*) 13

2\. Pre-alar markings consisting of large, subtriangular patches of silvery scales; each front tibia with a prominent apical spine curved inward
1\. *philonuxia*, n. sp.
Pre-alar markings narrow, forming lines of whitish or bluish scales; no apical incurved spine on tibiae 3

3\. Pleurae with large patches of white or bronzy scales entirely covering the anepisternum to the upper margin of the sclerite, no suggestion of a median horizontal line 4
Pleural white scaling somewhat restricted, suggesting a line more or less continuous with the pronotal and head patches of light scales; upper margin of the anepisternum therefore bare† 5

4\. Pleural scale patch snow-white, margined by bristles above and behind only; legs of male remarkably modified, the front and middle tarsi with first (metatarsal) segments shorter than the second ... ... 2. *pallidocephala*
Pleural scale patch bronzy yellow, margined with bristles before as well as above and behind; legs of male normal ... ... 3. *coeruleocephala*

5\. Abdomen banded 6
Abdomen plain or, at most, with pale apical lateral spots present 10

6\. Hind tarsi concolorous 7
Hind tarsi banded with white 9

7\. Abdominal segments 2 and 4 only (not 3) with pale apical bands ... 4. *alba*
Abdominal segments 1 to 4 pale apically or entirely pale 8

8\. Abdominal segments 6 and 7 with pale basal bands; no longitudinal pale lines on legs ... ... 5. *alboabdominalis*
Abdominal segments 6 and 7 with pale apical lateral patches; white lines along the mid and hind femora outwardly ... ... 6. *mayeri*

9\. Pleurae mostly dark brown, traversed across the middle by a light band in the integument beneath the line of white scales ... ... 7. *montana*
Pleurae mostly light brown, the line of white scales very narrow; vein R and R_1 clothed to the middle of the wing with white scales ... ... 8. *connali*

10\. Pleural scale patch narrow; white scales on vein R to the middle; larger species, 2·5 mm. 11
Pleural scale patch broad; white scales on vein Cu basally; smaller species, 2 mm. 12

11\. Hind tarsi banded with white ... ... 9. *bilineata*
Hind tarsi concolorous ... ... 9a. *bilineata* var. *fraseri*

* For a discussion of generic characters see Edwards (1912 and 1922) and Barraud (1926). *U. unguiculata*, Edw., a specimen of which was captured in Egypt by Gough, is not included in this discussion. It is chiefly an Eastern Mediterranean species and apparently of rare occurrence in North-east Africa. It is near *U. bilineata*, but the claws of the male are unequal and the upper fork-cells of the wings not so much shortened as usual.

† Although a spur of the lateral scaling in *caliginosa* normally extends downwards to the katepisternum, light integumental areas in the bare sclerites on either side give an appearance of a broad pleural band in line with the light scales on the pronotal lobes and head.

12. Abdominal segments with lateral, apical pale patches on all the segments; no pre-alar black spot in the integument ... ... 10. *balfouri*
Abdominal segments concolorous; a pre-alar black spot in the integument usually evident under the line of blue scales ... 11. *caliginosa*, n. sp.

13. Prothoracic lobes and the eye margins with bluish scales ... ... 12. *neireti*
Prothoracic lobes and eye margins without blue scales; head scales dark (except whitish in *annulata*) 14

14. Pleurae with dark upper and pale lower halves abruptly contrasting; hind tarsi with last two segments whitish 20
Pleurae more or less unicolorous; all tarsi dark 15

15. Mesonotum with prominent dark markings in the integument in front of or above the base of the wings 16
Mesonotal integument unicolorous 17

16. Pre-alar markings consist of an ovoid black spot on either side 13. *mashonaensis*
Pre-alar markings in the form of dashes running diagonally and dorsally, giving the mesonotum the appearance of a conspicuous dark "cap" between the wings, the rest of the thorax before and below being pale or yellowish 14. *ornata*

17. Integument of thorax chiefly yellow, contrasting with the black legs ... 18
Integument of thorax and legs brown 19

18. Scales of mesonotum concolorous with integument, yellow ... 15. *nigripes*
Scales of mesonotum black, contrasting with yellowish colour of integument 16. *pandani*

19. Pleurae dark brown, scales lighter brown ... ... 17. *inornata*
Pleurae light ochreous, scales somewhat bluish ... ... 18. *fusca*

20. Head scales pale; first three hind tarsal segments banded with white 19. *annulata*
Head scales dark brown; first three hind tarsal segments uniformly dark 20. *candidipes*

In discussing *U. mashonaensis*, Edwards (1912) says of those species included under *Pseudoficalbia* by Theobald " . . . the name should not be retained as a subgenus, as there seems no important structural character to distinguish these species from the rest." However, he has again accepted the subgeneric division of the African species in his 1927 unannotated list of African mosquitoes (Schwetz, 1927). This subgeneric assignment has been retained in the foregoing key.

On the other hand, in 1915 he had also called attention to the substantiation of the subgenus, *Pseudoficalbia*, by the characters of the larval head, presumably in reference to the rounded rather than elongate shape, and to the slender, bristle-like mid-frontal hairs as seen in *U. nigripes*. Unfortunately, two recently described larvae of African species have proved to be irregular in one or the other of these respects. *U. mashonaensis*, a member of the above subgenus, has spine-like mid-frontal hairs on the larval head. Conversely, the larva of *U. bilineata* var. *fraseri* has a head "as wide as it is long," unlike the more elongate heads observed in *U. abdominalis* and *balfouri* which had been considered typical of *Uranotaenia* sens. str.

Obviously, after considering both immature and adult characters, certain groups of species are seen to be more closely related to one another than to the subgeneric group as a whole, so that phylogenetically, probably more than two subgenera are represented in the African species of this genus. Additional species will undoubtedly be forthcoming from this region, and with more complete knowledge of the immature stages, an adequate subgeneric treatment can be arrived at, if it seems to be indicated when such information is completed.

The known larvae of *Uranotaenia* from Africa are quite characteristic, having more or less heavily chitinised plates on either side of the eighth abdominal segment to which the comb is attached posteriorly, the latter consisting of a single row of either fringed scales or sharp-pointed spines. The mental plate is well arched and small, with a varying number of teeth on either side of the central tooth. The antennal hair tuft is replaced by a single hair; in rare instances it is entirely absent. The mid-frontal hairs are single, and either slender, bristle-like or heavy and spine-like.

The pupae have rather broad, rounded, or subtriangular paddles, with or without external buttresses, with midribs, terminal setae of varying lengths, and minute fringes of spicules distally. The trumpets vary in form and amount of infuscation.

Key to described African Uranotaenia *Larvae.*

1. Head noticeably elongated 2
   Head rounded, length and width approximately equal 3
2. Head heavily chitinised, whole larva in life dark in appearance ; comb rarely with more than 6 sharp-pointed spines, and pecten with 9 to 12 fringed scales *balfouri*
   Head lighter, larva light grey ; comb with 8 to 9 sharp-pointed spines and pecten with 12 to 15 fringed scales ... ... *alboabdominalis*
3. Midfrontal hairs on head, thickened, appearing like spines 4
   Midfrontal hairs slender, bristle-like 5
4. Siphon little more than 3 times as long as the width at basal ring ; lateral comb with 6 to 8 fringed scales ; mental plate with 4 to 5 teeth on either side of central tooth ... ... *bilineata* var. *fraseri*
   Siphon index 5 ; lateral comb with 10 to 14 fringed scales ; mental plate with 11 to 12 teeth on either side ... ... *mashonaensis*
5. Lateral comb with less than 15 sharp-pointed *spines* ; anal papillae (gills) at least 3 times as long as the anal segment ; larvae 4 mm. or less 6
   Lateral comb with more than 15 fringed scales ; anal gills about equal to the anal segment ; larvae over 4 mm. 7
6. Anal gills about 3 times as long as anal segment ; siphonal hair tuft composed of about 8 hairs ... ... *nigripes*
   Anal gills about 4 times as long as anal segment ; siphonal hair tuft composed of 3 to 6 hairs ... ... *inornata* (*fusca*?)
7. Siphon index 4, and with tuft of 1 or 2 hairs ; lateral anal hair single *annulata*
   Siphon index 3, and with tuft of 4 hairs ; lateral anal hair double ... *candidipes*

Key to described Pupae.

1. Trumpets long, narrow, orifice practically circular without deep notch ; lateral setae on all abdominal segments single, that on the eighth reaching to the tip of the anal paddle ... ... *candidipes* (also probably *annulata*)
   Trumpets short, broad, or when elongated, orifice on one side with notched or extended rim ; lateral setae on segment VIII at least, multiple... ... 2
2. Abdominal segments III to VII with all sublateral and submedian setae (B and C of Macfie) composed of two or more hairs 3
   Abdominal segments VI and VII at least, with some of these setae single ... 5
3. Trumpets short and wide, no extensive infuscation or deep notch; sublateral setae (B) on segments V to VII double or at most triple ... ... *mashonaensis*
   Trumpets moderately narrow tapering with noticeable infuscation basally and sometimes apically and with deep notch in rim ; sublateral setae (B) on V to VII, multiple with six or more branches 4

4. Pupa small when extended, 2·8 mm.; trumpet infuscated at apex as well as basally ... ... *balfouri*
Pupa larger, over 3·5 mm.; trumpet infuscated basally only *bilineata* var. *fraseri*

5. Lateral setae (A) on segment VII nearly as long as succeeding segment; sub-median seta (P) on segment VIII branched ... ... *nigripes*
Lateral setae (A) on VII short; seta (P) single 6

6. Paddles subtriangular, somewhat elongate; terminal setae on midribs short but rather stout, curved at tip; lateral setae (A) on VIII with multiple hair of nine branches; sublateral (B) and submedian (C) setae on V and VI half as long again as the width of the following segment ... *inornata* (*fusca*?)
Paddles rounded, terminal setae also short, but slender; lateral setae on VIII three or four branched; all setae on abdominal segments short ... *ornata*

The following remarks refer particularly to species for which new localities or other data have accumulated since Edwards' valuable treatise in 1912. The unstarred territories are listed in that article; new localities are starred(*). The numbers correspond to the respective species in the preceding key to the adults.

1. Uranotaenia philonuxia, n. sp.

Length, 2·5 mm. *Head* clothed with flat, silvery white scales (bluish in certain lights), a few dark brown upright scales posteriorly. Proboscis slightly swollen at the tip; about equal in length to the abdomen in the male, a little longer in the female. Antennae of male equal in length to the proboscis; those of the female exceeding it by slightly over the length of the two terminal segments. *Thorax* dark brownish, grading somewhat lighter on the pleurae ventrally. Mesonotum covered with narrow dark brownish scales and rather long black bristles, the scutellum with the usual flat brownish scales. Large patches of silvery white scales in the pre-alar areas, on the pronotal lobes, and posterior anepisterna but not extending down to the katepisterna, nor to the coxae as in *caliginosa* (described later). Posterior pronotums bare, dull greyish in certain lights. *Abdomen* dark brown above and below, with purplish iridescent scales, devoid of markings. *Legs* dark brown, lighter on the femora beneath. Each of the front tibiae with a strongly incurved spine on the underside apically. Claws typical. *Wings* with dark brown partly outstanding scales on the veins. Base of cubital vein with flat white scales for about one-fourth its length to the wing margin. Ratio of the upper fork cell to its stem is as 4 : 7.

Type ♂. NIGERIA: Ebute Metta, 10.vii.1929, taken in roofless outbuilding in Botanical Gardens (*C. B. Philip*).

Type ♀. Same situation, 3.vi.1929. Presented to the British Museum.

Paratypes. Ebute Metta, 3.v, 1♀; 3.vi, 3♀; 1.vii, 2♂ and 3♀; 10.vii, 4♂ and 3♀; 8.viii, 11♂ and 5♀; 7.ix, 1♂ and 2♀, 1929. Lagos, Onikan servants' quarters, 4.vii.1929, 1♂ and 4♀. Yaba, bush, 17.vii.1929, 1♂ and 4♀. Apapa, crab-holes, 18.vii.1929, 2♂.

This is a very dark species, easily distinguished by its subtriangular (in place of the usual linear) patch of silvery scales in front of the base of the wings (see fig. 2), and by the apical incurved spine on the front tibiae below. It appeared to prefer the darkest recesses it could find and was not observed flying in the daylight.

2. Uranotaenia pallidocephala, Theo.

Sudan; Uganda; *Nigeria.

This species is listed by Graham (1910) from Lagos and is reported as a swamp breeder by Brown (1929). No specimens came to the writer's attention during several months of active collecting in the vicinity.

3. Uranotaenia coeruleocephala, Theo.

A considerable series of both sexes of this species was collected in Ebute Metta by the writer; no larvae were taken. It has been represented heretofore in London only by the type female from Bonny, Nigeria, and in Liverpool by a specimen from the *Belgian Congo (Schwetz).

It is now definite that *coeruleocephala* is distinct from *pallidocephala*, a doubt concerning which was raised by Edwards (1912) pending capture and comparison of the males. The legs of the male prove to be entirely normal in the present species. The type female is somewhat rubbed, but the bronzy scales on the pleurae are distinct. In normal specimens this patch of scales practically covers the posterior anepisternum with some scales on the outside of the first pair of coxae. In addition, the species is unique in having a row of bristles along the anterior as well as the upper and posterior margins of that sclerite, an observation particularly emphasised in conversation with Mr. Edwards.

The forward prolongation of this row of bristles was apparently overlooked by Theobald, as they are quite distinct in the type specimen also. In his original description (1901) he speaks of one male as having a " very marked lateral white spot composed of flat white scales in the mesopleura." This specimen, as mentioned by Edwards, proves to be *U. balfouri*.

4. Uranotaenia alba, Theo.

S. Rhodesia; *Kenya; Transvaal.

The Nairobi specimen listed by Edwards (1926) was not available for study, so that the doubt raised in 1912 as to the identity of this species with *U. alboabdominalis* on the basis of the single type specimen of *U. alba* still holds until more material accumulates. This species has also been listed by Ingram & De Meillon (1927) as having been taken in the Northern Transvaal in the larval and adult stages, but no description of the larva is presented.

5. Uranotaenia alboabdominalis, Theo.

Sudan; Uganda; *Gold Coast; *Belgian Congo.

The pale markings on the head and abdomen are quite variable in extent. Some specimens in the series from the Congo show the same variations in this respect as those mentioned by Edwards for material from Uganda, the bands on the sixth and seventh abdominal segments in a few being represented only by sparse pale scales basally. However, all the specimens agree in having the fifth segment entirely dark-scaled.

The larva has been described by Macfie & Ingram (1916) from marshy ground along a stream at Sunyani, Gold Coast.

6. Uranotaenia mayeri, Edw.

Nigeria; Gold Coast; *Sierra Leone.

7. Uranotaenia montana, Ingram.

The specimens of the type series described by Ingram (1927) from Zululand remain the only representatives of the species in the collection to date.

8. Uranotaenia connali, Edw.

Gold Coast; *Sierra Leone.

9. Uranotaenia bilineata, Theo.

Gold Coast (Ashanti); Uganda.

9a. Uranotaenia bilineata var. **fraseri**, Edw.

Uganda; *Belgian Congo; *Nigeria; *Zululand.

Dalziel (1920) found the larvae and adults in crab-holes at Lagos. One female was also taken as an adult by the writer in that situation.

Ingram & De Meillon (1927) captured and described the larval and pupal stages from a " grass-grown pool " near a railway in Zululand.

10. Uranotaenia balfouri, Theo.

Sudan; Gambia, Nigeria; Gold Coast; *Sierra Leone.

Larvae of this species were reported by Graham from borrow-pits near Lagos as quoted by Wesché (1910), who briefly describes the larva and pupa. Macfie & Ingram (1923) present further descriptions of both these stages collected in association with water lettuce. A series of adults was also bred from larvae taken in a swamp near Yaba by the writer.

11. Uranotaenia caliginosa, n. sp.

Length, 2 mm.

Head clothed with flat blackish scales, giving deep coerulean iridescence at certain angles. A narrow margin of flat whitish scales extends around the eyes expanding posteriorly to about the width of the whitish scale patch on the pronotal lobes. Proboscis brown, darker on the slightly swollen tip in some specimens; in the male, of about the same length as the abdomen, somewhat longer in the female. Male antennae longer than the proboscis by about the last two segments, those of the female longer by their four terminal segments. *Thorax* dark chocolate-brown. A black, velvety spot occurs in the integument in front of the base of the wings similar to but less prominent than that found in *U. mashonaensis*. Superimposed across the lower part of this spot is a line of flat, narrow, bluish white scales. Flat whitish scales on the pronotal lobes extending down along the proepisterna. Similar scales over most of the posterior anepisterna of the mesothorax, continuing down the posterior part of the katepisterna; the upper margin of the former bare. The posterior pronotums and anterior anepisterna also bare; the upper half of the former dark, concolorous with the mesonotum, sharply demarked from the integument of the lower half which is pale with iridescent indications in certain lights, as if it were pollinose. The mesepimera are also bare and almost as pale in certain lights as the lower part of the posterior pronotum. The general effect of these sclerites, plus the pale scaling on the sides, is of a light broad line running from the head and the pronotal lobes back across the pleurae. *Abdomen* blackish brown above, light brown below with pale scales scattered over the sternites. *Legs* brown, darker on the outer surfaces of the femora. Flat white scales outwardly on all the coxae. Claws of male typical. *Wings* with the usual dark brown scales; flat white scales on the bases of veins C and R equal to the length of the alula, and on veins M and Cu extending from a point opposite the axillary excision for about one-fifth of their length to the wing margin. Ratio of upper cell to its stem as 1 : 2.

Type ♂. NIGERIA: Ebute Metta, near Lagos, i.vii.1929, in outbuilding (*C. B. Philip*).

Type ♀. NIGERIA: Ebute Metta, near Lagos, 10.vii.1929, in outbuilding (*C. B. Philip*).

Presented to the British Museum.

Paratypes. Ebute Metta, Botanical Gardens, 15.iv, 1 ♂; i.vii, 1 ♂ and 2 ♀; 10.vii, 1 ♂ and 2 ♀; 7.viii, 2 ♂; 8.viii, 1 ♂ and 3 ♀; 17.ix, 1 ♂, 1929. Lagos, Onikan servants' quarters, 4.vii.1929, 1 ♀ (blooded, probably fowl). Apapa, crab-hole 18.vii.1929, 1 ♀.

The black integumental spot surmounted by a thin line of bluish scales in the pre-alar area is distinctive. In a few particularly dark specimens, the black pre-alar spots are not so distinct as in the usual forms, but these may be readily separated from *balfouri*, which they somewhat resemble, by the lack of abdominal markings. Like *philonuxia*, this species was taken only in dark recesses, and once in a heavily shaded crab-hole.

12. Uranotaenia neireti, Edw.

This species was described by Edwards in 1919 from Madagascar; certain specimens which had previously been classified under *U. fusca* from Uganda appear in Mr. Edwards' opinion to belong here. Comparison with the types, which are in the Paris Museum, remains to settle the question.

13. Uranotaenia mashonaensis, Theo.

Uganda; Gold Coast; Nigeria; Rhodesia; *Zululand; *Transvaal; *Tanganyika; *Kenya; *Belgian Congo.

Three females from Elizabethville are especially dark but otherwise typical. This species was of moderate occurrence in the vicinity of Lagos, having been captured in an outbuilding, in shaded vegetation near Ebute Metta, and in the "bush" (dense undergrowth) near the Commission compound at Yaba.

The larva and pupa have been described by Ingram & De Meillon (1927) from specimens captured in a shaded forest pool in Zululand (Natal). Larvae were also taken by them in the Transvaal, breeding in rock-pools.

14. Uranotaenia ornata, Theo.

Gold Coast (Ashanti); Uganda; *Sierra Leone.

Larvae were taken by Miss Evans in a mango tree-hole and in "the axils of a large dracaena-like shrub," and are reported from "the whorls and axils of the leaves of plants" by Bacot (1916). In Nigeria adults were of not infrequent occurrence in an outbuilding in Ebute Metta between June and September.

The terminal segments of the pupa were figured by Bacot.

15. Uranotaenia nigripes, Theo.

Sierre Leone.

"Atypical specimens approaching *ornata*" were reared by Miss Evans from larvae taken in rock-pools near Freetown. The larva has been described by Edwards (1916), and, together with the pupa, by Wigglesworth (1929).

16. Uranotaenia pandani, Theo.

A series of specimens studied by Theobald from the Seychelles Islands was later reduced to synonymy with *nigripes*, but has since again been considered as distinct by Mr. Edwards on the basis of the characters presented in the key supported by the wide difference in locality.

17. Uranotaenia inornata, Theo.

In reinstating this species which had been formerly placed as a synonym of *U. fusca*, Edwards (1926) states ". . . the scales of the pleurae are always light brown, not blue as stated by Theobald for *U. fusca*, and further, the pleural integument and the posterior pronotal lobes in *U. inornata* are largely dark brown, in *U. fusca*

entirely light ochreous." Ten specimens of both sexes of *inornata* are in the British Museum collection from Uganda, *Anglo-Egyptian Sudan, *Belgian Congo, and *Kenya. The type from the Transvaal is badly damaged.

Macfie & Ingram (1923) have described both the larva and pupa from the Gold Coast, inhabiting rock-pools. None of their reared specimens was available, so labelled, but a male of *U. fusca* from the Gold Coast dated 1922 collected by Ingram makes it probable that they were dealing with the following species rather than the more eastern *inornata*.

18. **Uranotaenia fusca,** Theo.

The type is from Sierra Leone. Ten additional specimens are from Sudan, *Gold Coast, and *Belgian Congo. Distinguishing characters are discussed under the preceding species.

19. **Uranotaenia annulata,** Theo.

Gambia ; Nigeria ; Gold Coast (Ashanti) ; *Uganda.

The extreme base of vein R is white-scaled to a point opposite the axillary excision, contrary to Edwards' statement (1912) that " there are no white scales on the wing-veins."

This species was the most abundant representative of the genus captured in the vicinity of Lagos. It was most frequently taken in both the immature and adult stages from crab-holes, where it was exceeded in numbers only by *Culex rima*, Theo. It was found breeding throughout the year as long as subsurface water or seepage maintained standing water in these holes.

The sex ratio among adult *U. annulata* caught in crab-holes was about 3·5 : 1, males predominating. Comparatively few females containing blood or eggs were present. Conversely, in collections from inside native quarters, although the total numbers were very much less, the females outnumbered the males in about the same proportion, more of the former containing blood or eggs in these situations.

Of a total of 1,470 adult *U. annulata* caught during a little over a year in various environments—crab-holes, tree-holes, underbrush, outbuildings, and occasionally in native quarters—74 of 403 females contained blood-meals less than 30 hours old. In precipitin tests on 66 of the latter, 7 gave positive results with anti-chicken sera and none with anti-human sera (Davis & Philip, to be published). The majority of the blood samples were badly altered when collected, or, when fresh, usually appeared to be " fixed," making testing difficult. Neither freshly emerged nor matured females were ever induced to bite monkeys in cage experiments, nor could they be induced to accept human blood-meals when liberated under the writer's bed-net. Fowl or other birds are therefore probably the hosts of their preference. Bacot (1916) also remarks on his inability to induce reared specimens of *U. ornata* to feed.

The larva of *annulata* from crab-holes at Sunyani on the Gold Coast has been described by Macfie & Ingram (1916).

20. **Uranotaenia candidipes,** Edw.

Transvaal.

This species is listed by Ingram & De Meillon (1927) from the Transvaal, where it was taken in the adult stage in undergrowth and crab-holes. The larva and pupa described by them were from crab-holes.

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TWO NEW SPECIES OF MALAYAN RHYNCHOTA.

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Specimens of the two Coreid bugs described below were submitted by the Entomological Division of this Department to the Imperial Institute of Entomology for determination and were returned shortly afterwards with the intimation that both were new to science.

From an economic point of view both species are of minor importance at present. The recorded host-plants for *Derepteryx* are the wild raspberries, *Rubus glomeratus*, Bl., and *Rubus rosaefolius*, Sm. *Ochrochira* was found originally on *Citrus* (lemon) at Tanah Rata. One example was also found on *Thea sinensis*, L. (tea), probably having flown there from an adjoining *Citrus* garden. This species was also found at Bukit Kutu feeding on *Citrus medica*, L., var. *acida*, Hook. (lime), *Hibiscus* sp. and *Cosmos bipinnatus*, Cav.

I have to thank Mr. W. E. China, of the British Museum (Natural History), for his trouble in comparing these two insects with their nearest known allies. His comparisons are given *verbatim*.

Family Coreidae.

Derepteryx chinai, sp. n.

Colour castaneous, densely covered with a fine fulvous pilosity. Antennal segments 1–3 dark ferruginous, with short dark brown setae ; segment 4 fuscous with a narrow dark ferruginous band basally. Dorsum of abdomen (except connexivum) dark orange. Membrane of hemielytra pale brownish ochraceous ; wings pale ochraceous.

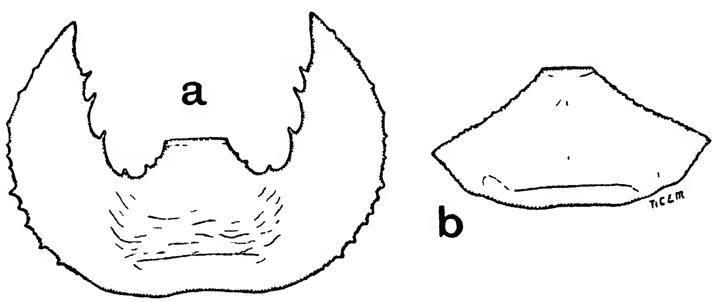

Fig. 1. Pronotum of : (*a*) *Derepteryx chinai*, sp. n. ; (*b*) *Ochrochira rubrotincta*, sp. n.

Pronotum (fig. 1, *a*) strongly rugose basally, less so on lateral lobes ; anterior area granulose. Posterior femora of ♂ (fig. 2, *a*) strongly incrassate, with five moderately stout short mucronate spines along middle of upper surface, an irregular series of shorter spines or tubercles below these, a stout spine at the middle of the posterior margin, a shorter spine close to it and between it and base of femur, and a spine near the apex on lower side of posterior margin ; outer and inner margin with a few short tubercles of various sizes, those on the outer margin reaching beyond the middle, lower surface less spinose or tuberculate. Posterior tibiae of ♂ (fig. 2, *a*) irregularly sinuate, with a round dilation on the inner margin near the base, a prominent tooth just past the middle, and a series of small tubercles between the tooth and the apex. Abdomen dilated, the outer margin of the connexivum extending beyond the costa of the hemielytra.

The female is similar in colour, but differs in structure from the male in having the posterior femora (fig. 2, *b*) slender and feebly spinose and the posterior tibiae simple.

Length, ♂ 25 mm., ♀ 28 mm.; width between pronotal angles, ♂ 13 mm., ♀ 14 mm.

FEDERATED MALAY STATES: Tanah Rata, Cameron's Highlands, 4,750 ft., 3 ♂♂, 3 ♀♀ (including type ♂—*N.C.E.M.*); The Gap, 2,798 ft., 1 ♂, 3 ♀♀ (*N.C.E.M.*).

" Distinguished from *lacticornis*, Bredd., *obscurata*, Stål, and *grayi*, White, by the absence of dilation of hind tibiae. Strongly resembles *D. hardwicki*, Walk., especially in the structure of hind tibiae (♂), which are curved with a distinct tooth on inner side below middle. Differs from *hardwicki*, Walk., in much smaller size, less arcuate and consequently narrower lateral pronotal lobes, fuscous instead of fulvous last antennal segment and more prominent internal tooth behind middle of hind tibia " (W. E. China).

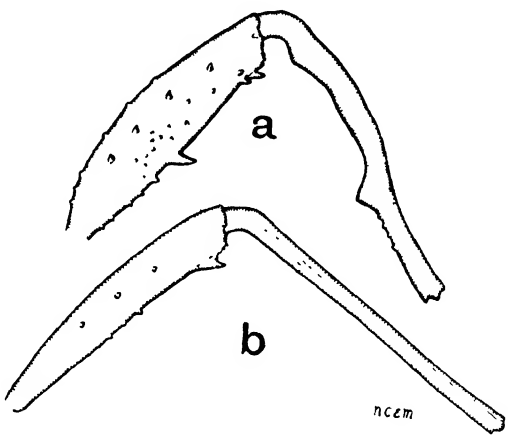

Fig. 2. *Derepteryx chinai*, sp. n., right posterior femur and tibia of: *a*, male; *b*, female.

Ochrochira rubrotincta, sp. n.

Colour of antennae dark brown. Head and pronotum dark reddish brown. Sternites and ventral surface of abdomen piceous, covered with a fine ochreous pubescence. Dorsum of abdomen dark reddish orange with a blackish suffusion; connexivum and segments 6–9 piceous. Femora, tibiae and apical segment of tarsi dark brown; segments 1 and 2 of tarsi pale ferruginous. Corium reddish brown; membrane infumate; wings ochreous, strongly infumate. The female is similar except that the corium is paler.

Pronotal lobes dilated and acutely angulate (fig. 1, *b*); lateral margins of pronotum strongly tuberculate; upper surface of pronotum rugosely punctate. Posterior femora of ♂ (fig. 3, *a*) incrassate, with a stout irregularly thickened spine at the middle of posterior margin, two broad teeth, contiguous basally on the lower margin apically and a moderately stout spine close to and between these and the median spine; upper and lower surfaces strongly and irregularly tuberculate, particularly on upper surface apically. Posterior tibiae of ♂ (fig. 3, *a*) with a feeble rounded dilation about the middle on inner margin, thence tuberculate to apex; outer surface sulcate throughout and with a short recurved projection apically.

The female differs from the male in being more robust, with the abdomen dilated laterally and extending beyond the costa of the hemielytra. The posterior femora are feebly incrassate (fig. 3, *b*), with a moderately prominent tooth, tuberculate on its apical margin, on the lower margin near the apex. Posterior tibiae simple.

Length, ♂ 25 mm., ♀ 27 mm.; width between pronotal angles, ♂ 10 mm., ♀ 10·5 mm.

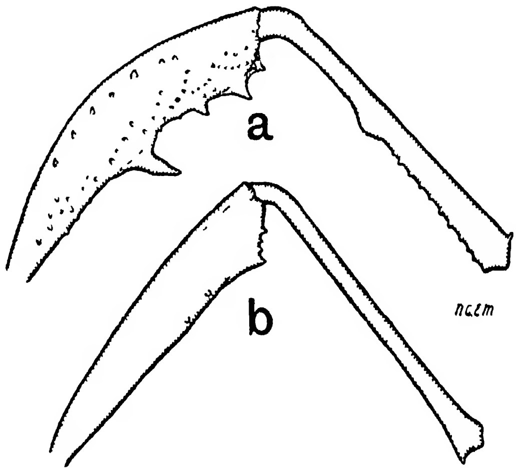

Fig. 3. *Ochrochira rubrotincta*, sp. n., right posterior femur and tibia of: *a*, male; *b*, female.

Federated Malay States: Tanah Rata, Cameron's Highlands, 4,750 ft., 8 ♂♂, 16 ♀♀ (including type ♂); Fraser's Hill, 4,280 ft., 1 ♂, 1 ♀; Bukit Kutu, 3,457 ft., 1 ♂, 1 ♀ (all *N.C.E.M.*).

" Differs from *biplagiata*, Walk., *albiditarsis*, Westw., *aberrans*, Dist., and *pallescens*, Dist., in the much less dilated pronotal lobes. Differs from *nigrorufa*, Walk., and *camelina*, Kirits., in its acutely angulate humeral angles, in which character it resembles *aberrans*, Dist. Differs from *aberrans*, Dist., in much smaller size, feebly dilated hind tibiae, with tooth towards base of inner margin very feebly prominent, and in much less laterally dilated pronotum " (W. E. C.).

The types of both species have been deposited in the British Museum (Natural History).

GALL MIDGES (CECIDOMYIDAE) WHOSE LARVAE PREVENT SEED PRODUCTION IN GRASSES (GRAMINEAE).

By H. F. Barnes, B.A., Ph.D.,

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1. Introduction.

Among the insects which do serious damage to grasses grown for seed, the larvae of gall midges (Cecidomyidae) are of great importance. Very little is known about their bionomics, except in the case of the Sorghum midge (*Contarinia sorghicola*), and the Meadow Foxtail midges (*Dasyneura alopecuri*, *Contarinia merceri*, and *Stenodiplosis geniculati*). In view of this and the fact that several grasses are grown for seed with advantage in Great Britain, it has been thought advisable to collect together all the available information.

In this paper the species of gall midges whose larvae have been reported as preventing seed formation in grasses are dealt with, the first reference mentioned being in each case that of the original description. A list of grasses whose seed production is affected by gall midge larvae is added. The cereals are not dealt with here.

A very useful publication, entitled " Report on a Survey of the Principal Seed-growing Counties of England, Wales and Scotland " (Min. Agric., Misc. Publ. no. 29, 1921, 99 pp.), is available. The title is self-explanatory.

Besides the midges mentioned, there are doubtless several others which have not yet been discovered. It is to be hoped that this paper will stimulate research on biological lines, so that remedial and preventive measures may be taken. The seed-growing industry in Great Britain is, as yet, in its infancy, but could have a very successful future.

2. Gall Midges whose Larvae prevent Seed Production.

The majority of midges whose larvae are known to prevent seed production in grasses belong to the genus *Contarinia*. Larvae of this genus are mostly yellow in colour, occasionally white. They are present in the grass heads only for a few weeks, and then migrate to the soil. Usually in an attack by larvae of this genus, the seed formation is prevented entirely, whereas in the case of an attack by a *Dasyneura* species the seeds form but are eaten away later.

1. *Lasioptera eriochloa*, Felt.

Felt, Mem. Dept. Agric. India, ix, 1926, p. 244.

Female described from specimens received from Mr. E. Ballard. Reared from ear-heads of *Eriochloa polystachya*, Coimbatore, 11.i.1922, Y. Ramachandra Rao.

2. *Dasyneura alopecuri* (Reuter).

Reuter, Act. Soc. Fauna and Flora Fennica, xi, 1895, pp. 6–9 (*Oligotrophus*).
Barnes, E. M. M., lxiii, 1927, pp. 214–215 (*Dasyneura agropyronis*) ; Ann. Appl. Biol., xvii, 1930, pp. 339–366 (*Dasyneura*) ; Jl. Min. Agric., 1930, pp. 694–697.

This midge has recently been dealt with in detail (Barnes, 1930) and there is no need to mention it further, except to state that its host-plant is *Alopecurus pratensis* (Meadow Foxtail grass).

3. *Dasyneura graminis*, Felt.

Felt, N.Y. St. Mus. Bull., no. 124, 1908, p. 342; N.Y. St. Mus. Bull., no. 175, 1915, pp. 135–136.

Female only described from specimen caught ovipositing in red-top or June grass (*Agrostis vulgaris*) in New York State in June 1907. Observed also in numbers ovipositing at the end of May 1908.

Recently midges which appear to be identical with this species have been reared from seeds of common Bentgrass collected and received from Mr. R. B. Dawson, near Keighley, Yorks. The larvae were fully grown early in August and the adults started emerging on 14th June the following year (1930) and continued for about a month. This material was parasitised to the extent of practically 34 per cent. by a minute Hymenopteron.

4. *Contarinia andropoginis*, Felt.

Felt, Mem. Dept. Agric. India, vii, 1921, pp. 25–26.
Ballard, Mem. Dept. Agric. India, vii, 1921, pp. i–ii.

Male and female described from specimens reared from ear-heads of cholam (*Andropogon sorghum*), 14.vii, South India, Coimbatore. The oviposition is described by Ballard.

5. *Contarinia arrhenatheri*, Kieffer.

Kieffer, Bull. Soc. Hist. Nat. Metz, xxi, 1901, pp. 33–34; Centralb. Bakt., Parasit. u. Infektionskr., Jena, Abt. 2, xlvi, no. 24–25, 1917, pp. 547–592 (R.A.E., A, v, 1917, p. 319).

Female only described from Lorraine. The lemon-coloured larvae live in the flower-heads of *Arrhenatherum elatius* (False Oat), turn into pupae in the soil and appear as adults at the end of the following May.

A single female (Cecid. 1,203) was caught ovipositing in Hertfordshire on 16th June 1928.

Kieffer (1917) records *Inostemma avenae*, Kieffer, as a parasite of this species.

6. *Contarinia avenae*, Kieffer.

Kieffer, Bull. Soc. Hist. Nat. Metz, xxi, 1901, pp. 32–33; Centralb. Bakt., Parasit. u. Infektionskr., Jena, Abt. 2, xlvi, no. 24–25, 1917, pp. 547–592 (R.A.E., A, v, 1917, p. 319).

Both sexes and the egg described from Lorraine. The lemon-coloured larvae live in the flower-heads of *Avena pubescens* (Downy Oat), turn into pupae in the soil and appear as adults at the end of the following May.

Keiffer later described *Inostemma avenae* as a parasite of this species.

7. *Contarinia brizae*, Kieffer.

Kieffer, Wien. ent. Zeit., xv, 1896, p. 99; Bull. Soc. Hist. Nat. Metz, xx, 1898, p. 32.

Male, female and larva very briefly described. The larvae feed in the flower-heads of *Briza media* (Common Quaking grass) in Lorraine.

8. *Contarinia caudata*, Felt.

Felt, Mem. Dept. Agric. India, vii, 1920, pp. 4–5.

Male and female described from specimens reared in December 1916 from ear-heads of *Apluda varia* and *Andropogon schoenanthus*, collected at Coimbatore, South India.

9. *Contarinia dactylidis* (H. Lw.).

Loew, H., Linn. Ent., Stettin, v, 1851, pp. 383–384 (*Cecidomyia, Diplosis*).
Kieffer, Bull. Soc. Hist. Nat. Metz, xx, 1898, p. 32 (*Contarinia*).

Female only described from orange-yellow larvae found in the flower-heads of *Dactylis glomerata* (Cock's-foot) in June in Germany.

10. *Contarinia eragrostidis*, Felt.

Felt, Treubia, ix, 1927, p. 381.

Male and female described after being reared from the seed-heads of *Eragrostis unioloides*, Nees, collected in Java in 1922 by Mr. C. A. Backer.

11. *Contarinia merceri*, Barnes.

Barnes, Ann. Appl. Biol., xvii, 1930, pp. 339–366; Jl. Min. Agric., 1930, pp. 694–697.

This species has recently been described and dealt with in detail, and there is no need to mention it further, except to state that its host-plant is *Alopecurus pratensis* (Meadow Foxtail grass).

12. *Contarinia saltata*, Felt.

Felt, Philippine Jl. Science, xiv, 1919, pp. 289–290.

Male only described from midges caught on a spider's web on a leaf of *Andropogon sorghum*. This species is quite distinct from *C. sorghicola*, Coq., and may possibly feed on the *Andropogon*.

13. *Contarinia sorghicola* (Coq.).

Coquillet, U.S. Dept. Agric., Div. Ent. Bull. 18, n.s., 1898, pp. 81–82 (*Diplosis*).
Dean, U.S. Dept. Agric., Bur. Ent. Bull. 85, pt. 4, 1911, pp. 39-58 (*Contarinia*).
Felt, N.Y. St. Mus. Bull. no. 202, 1918, pp. 106–110.
Gable, Baker & Woodruff, U.S. Dept. Agric., Farmers' Bull. no. 1566, 1918, 9 pp.

This midge is very well known throughout the principal sorghum-producing sections of the United States of America, on account of the great losses caused to the grain sorghums and the seed crops of other sorghums, broomcorns, and Sudan grass. It also occurs on Johnson grass, *Setaria glauca*, *Sieglingia seslerioides*, and tall red-top (*Triodia flava* (L.) Hitchc.). The larvae are pink to red in colour, which is unusual for *Contarinia* larvae, and further, pupate in the seed-heads. Full descriptions of the different stages, biology and remedial measures are given in the above references.

Among the natural enemies are the parasites, *Aprostocetus diplosidis* and a *Tetrastichus*; the Argentine ant, *Iridomyrmex humilis*, Mayr; and a fly, *Psilopodinus flaviceps*, Aldr., preys upon the midges.

Further references are given by Felt (1918).

14. *Stenodiplosis geniculati*, Reuter.

Reuter, Act. Soc. Fn. Flora Fennica, xi, 1895, pp. 10–14.
Barnes, Ann. Appl. Biol., xvii, 1930, pp. 339–366; Jl. Min. Agric., 1930, pp. 694–697.

This species has recently been dealt with in detail, and there is no need to mention it further, except to state that its host-plant is *Alopecurus pratensis* (Meadow Foxtail) and *A. geniculatus* (Marsh or Floating Foxtail). There are specimens from New Zealand in Dr. E. P. Felt's collection at the State Museum, Albany, N.Y.

15. *Cecidomyia penniseti*, Felt.

Felt, Mem. Dept. Agric. India, vii, 1920, p. 11.

Female only described, and reared from ear-heads of *Pennisetum typhoideum* at Coimbatore, S. India. Dr. Felt states that it is possibly predacious.

16. *Itonida penniseti*, Felt.

Felt, Mem. Dept. Agric. India, vii, 1920, pp. 9–10.

Male and female described, and reared from ear-heads of *Pennisetum cenchroides* at Coimbatore, S. India.

17. *Itonida seminis*, Felt.

Felt, Mem. Dept. Agric. India, vii, 1921, pp. 26–27.

Male and female described, and reared from ear-heads of cumbu (*Pennisetum typhoideum*) at Coimbatore, S. India.

18. *Itonida setariae*, Felt.

Felt, New Species of Cecidomyiidae, ii, 1907, pp. 22–23 (*Cecidomyia*); N.Y. St. Mus. Bull. no. 124, 1908, pp. 303–304, 414 (*Cecidomyia*); N.Y. St. Mus. Bull. no. 200, 1918, p. 24 (*Itonida*); N.Y. St. Mus. Bull. no. 231–232, 1921, pp. 191–192.

Male only described. Reared from seeds of *Setaria glauca* at Albany, N.Y. State. In Dr. Felt's references he stated that it was bred from common foxtail grass, *Alopecurus pratensis*. I pointed this out to Dr. Felt during a visit to him and also that the specific name was *setariae*. The original field book and specimens were examined and it was clear that by using the American common name (common foxtail grass) of *Setaria glauca* a mistake was subsequently made when the Latin name was added; this should have been *Setaria glauca*, not *Alopecurus pratensis*. In the collection at the State Museum, there is a seed of *Setaria glauca* with the pupal case protruding, together with the pinned material of *I. setariae*, Felt. This is supporting evidence.

Unidentified Gall Midges.

In addition to those species of midges which have been described, there are several records of unidentified midge larvae. Trotter (Marcellia, vi, 1907, p. 102) records a Cecid. larva on *Andropogon distachyus* heads in Italy. Bagnall & Harrison (Trans. Ent. Soc. London, 1917, p. 409, 1918) record larvae in the spikelets of *Dactylis glomerata* (Cock's-foot) in Durham; these may be *Contarinia dactylidis* (H. Lw.). The writer has received larvae in the pales of *Festuca rubra* var. *arenaria* collected in Oxfordshire. Bagnall & Harrison (*loc. cit.*, p. 409) record yellow larvae in spikelets of *Phleum pratense* (Timothy) in Durham; and the writer has also received larvae from the seed-heads of the same grass. The same authors (*loc. cit.*, p. 409) record minute yellow larvae in the spikelets of *Poa* sp. (Meadow grass) in Northumberland and also in Durham (Ent. Rec., xxxvi, 1924, p. 53).

The biology of a Cecidomyid which caused a 90 per cent. loss of seed of *Poa pratensis* near Stettin in 1926 has been worked out by H. von Oettingen (*3. Wanderversamml. deuts. Ent. Giessen*, pp. 112–115, Berlin, 1929, and R.A.E., A, xviii, 1930, p. 662). Although the midge is undescribed, a figure was published as a supplement to an article in *Illustr. Landwirtschaftl. Ztg.*, xlvii, 1927, p. 659).

3. List of Grasses whose Seed Production is affected by Gall Midge Larvae.

GRASS.	MIDGE.	COUNTRY.
**Agrostis vulgaris* (Common Bent grass, June grass)	*D. graminis*, Felt ...	U.S.A., England.
**Alopecurus geniculatus* (Marsh or Floating Foxtail)	*S. geniculati* (Reuter) ...	Finland, England.
**Alopecurus pratensis* (Meadow Foxtail)	*D. alopecuri* (Reuter) ...	Finland, Denmark, Great Britain, Ireland, New Zealand.
	S. geniculati, Reuter ...	Finland, England, Wales, Ireland, Isle of Man, New Zealand.
	C. merceri, Barnes ...	Great Britain, Ireland, Finland.
Andropogon distachyus	Cecidomyid	Italy.
Andropogon halepense (Johnson grass)	*C. sorghicola* (Coq.) ...	U.S.A.
Andropogon schoenanthus	*C. caudata*, Felt ...	India.
Andropogon sorghum (cholam)	*C. andropoginis*, Felt ...	India.
	C. saltata, Felt ...	Luzon, P.I.
Apluda varia	*C. caudata*, Felt ...	India.
**Avena pubescens* (Downy Oat) ...	*C. avenae*, Kieffer ...	Lorraine.
**Arrhenatherum elatius* (False Oat) ...	*C. arrhenatheri*, Kieffer	Lorraine, England.
**Briza media* (Common Quaking or Totter grass)	*C. brizae*, Kieffer ...	Lorraine.
**Dactylis glomerata* (Cock's-foot) ...	*C. dactylidis*, Kieffer ...	Germany.
	Cecidomyid	England.
Eragrostis unioloides	*C. eragrostidis*, Felt ...	Java.
Eriochloa polystachya	*L. eriochloa*, Felt ...	India.
**Festuca rubra* var. *arenaria*	Cecidomyid	England.
Pennisetum cenchroides	*I. penniseti*, Felt ...	India.
Pennisetum typhoideum (cumbu) ...	*I. seminis*, Felt ...	India.
	C. penniseti, Felt ...	India.
**Phleum pratense* (Timothy, Meadow Cat's Tail)	Cecidomyid	England.
**Poa pratensis* (Smooth Meadow grass)	Cecidomyid	Germany.
**Poa* spp.	Cecidomyids	England.
**Setaria glauca* (Glaucous Bristle grass, Bristly Foxtail, Common Foxtail, Pigeon grass)	*C. sorghicola* (Coq.) ...	U.S.A.
	I. setariae, Felt ...	U.S.A.
**Sieglingia seslerioides*	*C. sorghicola* (Coq.) ...	U.S.A.
Sorghum saccharatum	*C. sorghicola* (Coq.) ...	U.S.A.
Triodia flava (Tall Red-top)	*C. sorghicola* (Coq.) ...	U.S.A.

Genus or species of the grass found in Great Britain.

A NEW PREDACIOUS GALL MIDGE (DIPT., CECIDOMYIDAE).

By H. F. Barnes, B.A., Ph.D.,

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Through the courtesy of the Imperial Institute of Entomology, I have been able to examine specimens of a remarkable gall midge reared by Mr. E. Hargreaves, in Sierra Leone, from larvae predacious on a species of mealy-bug.

The eyes are the most striking feature of this midge. Instead of the normal contiguous type (fig. 1, *a*) which approximate in the median line, there are three compound eyes, two lateral and the third median, dorsal and transverse (fig. 1, *b*). This peculiarity has previously been recorded only in the genus *Trisopsis*, Kieffer. In this genus four species, *T. oleae*, Kieffer, *T. alluaudi*, Kieffer, *T. bifida*, Brèthes, and *T. hyperici*, Tavares, have been described. The larvae of the first named were found in the fruit of *Olea verrucosa* at Wellington, S. Africa ; a female of *T. alluaudi* was caught in a forest at an altitude of 2,400 metres in Kenya ; *T. hyperici* was described as a commensal of *Geocrypta hypericina*, Tavares, from Spain ; and *T. bifida* was described from Buenos Aires.

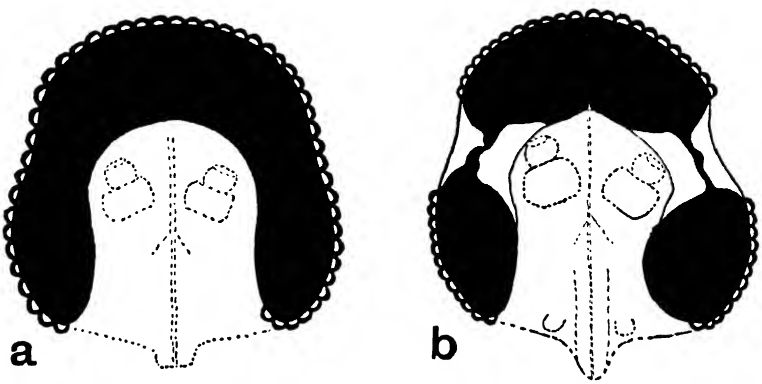

Fig. 1. Diagrammatic representation of front aspect of head showing : *a*, normal type of eye in Cecidomyidae (basal segments of antennae dotted) ; *b*, *Triommata coccotroctes*, gen. et sp. n., with dorso-median and two lateral compound eyes.

The species under consideration differs in several important features from the known species of *Trisopsis* ; consequently, it is thought advisable to raise a new genus for it.

Triommata, gen. nov.

The differences between this genus and *Trisopsis*, Kieffer, are as follows : The palps are 4-segmented (instead of three), the fifth vein is forked (instead of being simple), the claws on the anterior legs are toothed, while those on the mid- and hind-legs are simple (instead of all being simple), and the basal lobe on the proximal clasp segment is spinose.

If we follow Felt's keys (1925), this genus is located next to *Lobodiplosis*, Felt, among that section of the Trifila in which the anterior claws are toothed and the palps have four segments. This position is at a considerable distance from the genus

Trisopsis, which is in that section of the Trifila in which all the claws are simple and the palps have three segments. On the other hand, in Kieffer's keys (1913) it would be next to *Trisopsis* in the division of Cecidomyiariae which possess three compound eyes as distinct from that in which there are two compound eyes. This is presumably its correct phylogenetic position. It seems inconceivable that such characters as the structure of the claws and number of palp segments have more importance in this respect than the structure of the eyes. The peculiarity of three compound eyes is restricted in the CECIDOMYIDAE to the genera *Trisopsis* and *Triommata*. It is considered therefore most probable that these two genera are, phylogenetically, closely allied and have not arisen independently.

Triommata coccotroctes, sp. n.

Male. Length about 1·25 mm. Eyes (fig. 1, *b*): three compound, one dorsal and transverse, two lateral, the latter connected by a band of pigment to the dorsal eye, the distance between the lateral and dorsal eyes nearly equal to the length of the lateral eye. Antennae: 2+12, basal enlargement subglobular, bearing setae and one ring

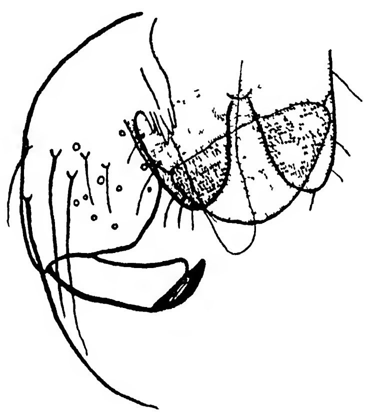

Fig. 2 *Triommata coccotroctes*, gen. et sp n. male genitalia.

of regular circumfila, about ten loops as long as length of enlargement, distal enlargement slightly elongated, with two rings of regular circumfila, the loops of the same size and number as on basal enlargement, stem and neck of approximately equal size, basally slightly longer than broad, distally about twice as long as broad. Palps: 4 segments, all with short setae, basal segment globular, second oblong, slightly more than twice as long as broad, third about three times as long as broad, distal segment about the same as, or slightly longer than, third. General body colour reddish brown. Wings: hyaline, 3rd vein reaching tip of wing, costa interrupted at this point, 5th vein forked. Legs: claws strongly curved, much longer than empodium, anterior ones with distinct tooth, mid- and hind-claws simple. Genitalia (fig. 2): basal clasp segment short, broad, with some extremely long setae, basal lobe spinose; distal clasp segment short, stout; dorsal lamella bilobed, each lobe broadly rounded, with short setae; ventral lamella entire, broadly rounded, large; style stout.

Cotypes, Cecid. 1527, 1528, 1529, 1530.

Female. Length about 1·5 mm. Eyes as in male. Antennae : flagellar segments cylindrical, with short broad necks about twice as wide as long, circumfila applied. Ovipositor lamelliform, two lateral and a smaller median basal lamella. Otherwise about as in male.

Cotypes, Cecid. 1531, 1532, 1533.

Pupa. Cecid. 1534, 1535, 1536.

Larva. Red, predacious mouth-parts, bilobed breast-bone. Cecid. 1537, 1538.

Other species of males, females, pupae and larvae, coll. 4934 Imp. Inst. Ent.

Locality. Njala, Sierra Leone (*E. Hargreaves*), 1–28.xi.1930.

Habit. Predacious on mealy-bug.

NOTES ON THE BIOLOGY OF *LAPHYGMA EXEMPTA*, WALK., AND *L. EXIGUA*, HBN. (LEP., NOCTUIDAE).

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The following notes are the result of investigations carried out at Barberton, in the Eastern Transvaal.

Laphygma exempta, Walk.

The larva of this species is the common army, or mystery, worm, which periodically causes serious loss to maize growers. In addition to maize, it also attacks crops such as kaffir-corn, teff, oats, wheat and millet. The natural food-plants are grasses, and many miles of veld are frequently stripped bare of these by the pest.

The origin of the outbreaks, which take place at irregular intervals, is uncertain, and it is not possible to predict when, or where, they will occur. Three infestations sometimes take place during a season, but the first is usually more extensive than the succeeding two.

Egg.—The eggs are deposited, upon the leaves of the food-plant, in clusters consisting of one or two layers, and are covered with blackish, down-like scales from the body of the parent. The number of eggs in a cluster varies ; in the laboratory it has varied from 43 to 220. The incubation period occupies from 3 to 8 days, according to temperature.

Larva.—Under laboratory conditions the larval period varied, during March, from 18 to 24 days, with an average of 21 days. At midsummer, and under natural conditions, the period is probably several days shorter. Artificial conditions seem to lengthen the larval stage. When full-grown, the larva enters the soil and constructs an earthen cocoon just beneath the surface.

Pupa.—The duration of the pupal period varies considerably with the time of year. During February it occupied from 12 to 17 days, with an average of 14 days ; from mid-March to mid-April periods of 15 to 21 days were obtained, with an average of 18 days ; while from mid-May to the end of June the period varied from 29 to 36 days, the average, in this case, being one of 33 days.

Adult.—During the day large numbers of adults are frequently to be seen flying about among the vegetation, sometimes attended by flocks of swallows, which prey upon them. It is probable that the adults migrate, and, if so, this would help to account for the sudden appearances and disappearances of the species. In this connection it may be mentioned that in 1929, although a second generation of adults was present in large numbers, the moths suddenly disappeared, and no larvae were subsequently found. The female has lived for as many as 21 days under laboratory conditions, and oviposition, which takes place at night, has been found to commence at any time from the third to the eighth day after emergence, but generally on the fourth day. The largest number of eggs obtained from one female was 682.

Natural Enemies.—Two species of ICHNEUMONIDAE, *Disophrys iridipennis*, Cam., and *Chelonus erythropus*, Cam., have been obtained from the larva, also a Chalcid and a Tachinid.

Laphygma exigua, Hbn.

Commonly known as the lesser or false army worm, and the pigweed caterpillar, this species, in the Eastern Transvaal, occurs mainly as a pest of cotton and of peas. Elsewhere in the Union it has been recorded as attacking maize, tobacco, grape vines,

garden beets, and young eucalyptus trees,[2] as well as being injurious to lawns.[1] In addition, several wild food-plants have been found, the commonest of which is the pigweed (*Amarantus paniculata*).

During the summer months the larva attacks cotton, the most severe and noticeable infestation usually commencing early in January. Serious damage is sometimes caused, the young plants being almost completely defoliated. Young pea plants suffer extensively during the winter in the Barberton area and in the Low Veld. The damage is sometimes so severe as to necessitate replanting.

Egg.—The eggs, like those of *L. exempta*, are deposited in clusters on the leaves of the food-plant and are covered with down-like scales, almost white in colour. Clusters containing from 8 to 100 eggs have been deposited in the laboratory. The incubation period occupies from 3 to 7 days during the summer, while in winter it may be prolonged up to 12 days.

Larva.—There are five larval instars, the duration of which, from mid-March to early April, was as follows: First instar, 3 days; second instar, 2 to 4 days; third instar, 3 to 6 days; fourth instar, 4 to 5 days; fifth instar (up to time of entering soil), 4 to 6 days. The total larval period varied from 17 to 20 days, with an average of 18 days. During midsummer the period is somewhat shorter,[1] and in winter correspondingly longer. The larvae, on hatching, spin a loose web over the cotton leaves, on the lower surface of which they feed, while the upper epidermis is generally left intact. When older, the larvae become more scattered, and during the day hide in the soil. In the case of peas the young larvae are usually to be found among the unfolded leaves at the growing points, and when older hide in the soil during the day. When full-grown, the larva makes an oval earthen cocoon immediately beneath the surface of the soil, and pupation takes place two days later.

Pupa.—The duration of the pupal stage varies considerably. From January to March it occupied from 9 to 18 days, while the average from February to March was 13 days. Periods as short as 7 days have been recorded elsewhere.[1] The period gradually lengthens with the approach of winter, and the longest example obtained, during July–August, was of 48 days duration.

Adult.—The female has lived in captivity for periods up to a maximum of 15 days. Oviposition, which takes place at night, may commence on the third day after emergence. The adult of this species is also believed to migrate.

Natural Enemies.—Several parasites have been bred from the larva, the most important of which are a Tachinid and a Chalcid. The Chalcid deposits its eggs upon the dorsal surface of the larva, which dies when the parasite larvae hatch and commence feeding. Towards the end of the January infestation, the parasites are numerous, and the fact that there is only one serious infestation of cotton during the season is probably due to their action. During the winter the parasites do not appear to be so abundant, and the damage caused by the pest is more extensive.

References.

(1) BRAIN, C. K. A Preliminary Report on the Cotton Pests of S. Africa.—Union of S.A. Dept. Agric., Local Ser., no. 59, 1918.

(2) HOWARD, C. W. The Pigweed Caterpillar.—Transvaal Dept. Agric. Div. Ent., Leaflet no. 8.

DESCRIPTIONS OF SOME NEW FORMOSAN COCCIDAE (RHYNCHOTA).

By R. Takahashi,

Department of Agriculture, Research Institute, Formosa.

The present paper deals with a further nine species of Diaspinae which are new to science. I desire to express here my sincere thanks to Mr. E. E. Green for his invaluable assistance in working out my material.

All the type specimens will be preserved in the collection of the Department of Agriculture, Research Institute, Formosa.

Diaspis gordoniae, sp. n. (fig. 1.)

Adult female. *Scale* subcircular, somewhat narrowing towards the front end, convex, white, about 2·7 mm. in length, about 2·5 mm. in width. Larval skins on the anterior extremity of the scale, blackish brown.

Body black in dried specimens, about 1·2 mm. in length, about 0·9 mm. in width. Spiracles without parastigmatic pores. Abdominal segments defined, a little convex on the side, on the lateral area with some small glands which are smaller than those on the pygidium ; the last four segments each with many glands on the lateral area and on the hind margin of it, these glands similar to those on the pygidium ; the last segment with 5 or 6 gland spines ; the penultimate segment with 1–3 gland spines and about 5 shorter spine-like setae ; the anterior three segments each also with about 6 similar spine-like setae on the lateral part.

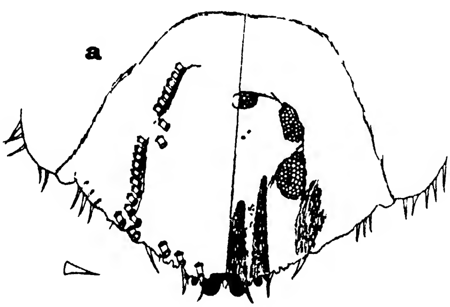

Fig. 1. *Diaspis gordoniae*, sp. n., adult female : *a*, pygidium ; *b*, spine-like seta on abdomen.

Pygidium wider than long, with many longitudinal lines on the dorsum, more chitinised on the posterior part of median area of the venter. Anal opening circular, larger in diameter than the gland orifice, nearer to the base than to the distal end. Dorsal gland orifices and marginal glands as shown in the accompanying figure. Circumgenital pores in 5 very dense groups, the median group with about 20 pores, the upper lateral with about 27, the lower lateral with about 35. Median lobes large, blunt, rounded, not serrate or notched, protruding, almost parallel, separated ; the 2nd lobes very small, divided. Gland spines a little longer than the median lobe, almost as long as those on the abdomen, 6 on each side.

Host. *Gordonia axillaris*, attacking the twig.

Hab. Taihoku.

Some specimens were collected by me on 27th December 1930. The male scales are white, a little widened towards the posterior end and about 1·7 mm. in length.

They are much more numerous than the females and grouped very densely around the twigs, being held vertically to the surface of the host. This species is closely related to *Diaspis major*, Ckll., and *D. grandilobis*, Green, but differs from the former in the shape of the median lobes and from the latter in lacking the 3rd lobes.

Aulacaspis robusta, sp. n. (fig. 2).

Adult female. *Scale* subcircular or broadly oval, somewhat convex, greyish or pale brownish white, about 3–3·5 mm. in length, about 2·5 mm. in width. Larval skins near the margin, pale yellowish brown.

Body variable in size, from 1 to 1·85 mm. in length, about 0·7–1·0 mm. in width. Cephalothorax widest near the hind end, with a very small protuberance on the side and about 20 short submarginal setae. Antennae with a long curved seta which is longer than the submarginal setae on the cephalothorax. Segments defined, convex on the side, the last segment with about 16 gland spines, the penultimate segment with about 5 similar spines, lacking glands on the median area. Anterior spiracles with many parastigmatic pores in a very dense group, posterior spiracles with about 7 or more similar pores in 2 or 3 groups.

Pygidium wider than long, with many longitudinal lines on the dorsum. Anal opening circular, larger in diameter than the dorsal gland orifice, nearly at the centre. Dorsal gland orifices and marginal glands as shown in the accompanying figure. Circumgenital pores in 5 very dense groups, the median group with about 40 pores, the upper lateral with about 65, the lower lateral with about 48. Median lobes

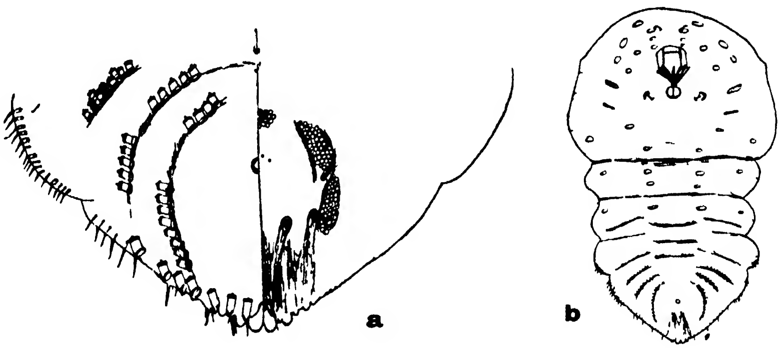

Fig. 2. *Aulacaspis robusta*, sp. n.: *a*, pygidium of adult female; *b*, adult female.

stout, rounded on the distal end, slightly serrate on the margin, parallel, united basally; the 2nd and 3rd lobes much smaller, rounded, divided. Gland spines slightly longer than the median lobes, about 10 on each side.

Host. *Bladhia sieboldii*, attacking the branch.

Hab. Shirin.

Described from specimens collected by me on 30th December 1930. The males group very densely and are more common than the females. This species is not a typical *Aulacaspis*, owing to the median lobes being contiguous for two-thirds of their length.

Aulacaspis murrayae, sp. n. (fig. 3).

Adult female. *Scale* almost circular or subcircular, somewhat convex, white, thick, untransparent, with no ridges, about 2–3 mm. in diameter. Larval skins pale brownish yellow, near the centre or submarginal; the 1st larval skin somewhat

extending beyond the front margin of the 2nd; the 2nd larval skin about 1·3 times as long as wide, about 0·8 mm. in length, pygidium with 4 pairs of marginal glands and 5 pairs of gland spines, the median lobes almost as in the adult.

Body large, about 1·6 or 1·7 times as long as wide, about 1·25 mm. in length. Cephalothorax somewhat widened towards the hind part, as wide as or a little wider than the widest abdominal segment, with a small protuberance on the side, a few short submarginal setae, a pair of transverse loose groups of very small glands in front of the mouth-parts (about 7–9 glands in each group), and a pair of larger groups of similar glands behind the mouth-parts (about 20 glands in each group), these glands wider than long. Antennae with a long curved seta. Anterior spiracles with about 20 parastigmatic pores in a dense group, hind spiracles with about 15 pores. Segments well defined, protruding laterally; metathorax and the 1st abdominal

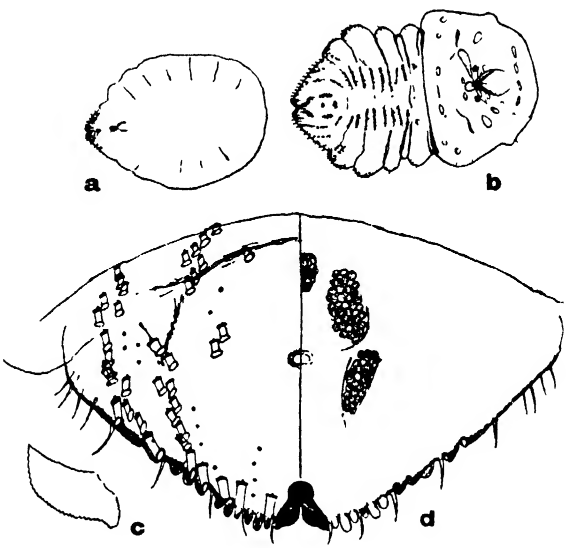

Fig. 3. *Aulacaspis murrayae*, sp. n.: *a*, second larval skin; *b*, adult female; *c*, median lobe, and *d*, pygidium, of adult female.

segment with a lateral seta and some very small glands on the lateral area; the 2nd abdominal segment the most prominent laterally; the 2nd and 3rd abdominal segments with many small lateral glands and many gland spines, these lateral glands much smaller than those on the pygidium and the gland spines somewhat shorter than those on the pygidium; abdominal segments with many short glands in transverse rows, these glands similar to those on the pygidium and also present in a group near the sides of the last two abdominal segments.

Pygidium wider than long, narrowly chitinised on the margin, with many longitudinal lines. Anal opening transversely oval, somewhat larger than the dorsal gland orifice, at the centre. Dorsal glands as shown in the accompanying figure. Marginal glands a little longer than the dorsal ones, distinctly protruding at the distal end, 7 on each side. Circumgenital pores in 5 dense groups, the median group with about 17 pores, the upper lateral with about 40, the lower lateral with 23–34. Median lobes in a cleft, divergent, closely placed, a little protruding out of the cleft, serrate on the margin, slightly indented on the inner edge near the apex, a little narrowed on the apical part, rounded at the tip, stout, larger than the marginal glands;

the 2nd lobes divided, rounded apically, not serrate, the inner lobules somewhat larger; the 3rd lobes divided, similar to the 2nd, but smaller; the 4th shorter. Gland spines a little longer than the 2nd lobes or marginal glands, 9–11 on each side.

Host. *Murraya exotica*, attacking the leaf.

Hab. Shinten, Taihoku, Toyen, Takao, Heito, Taito, Chippon.

Very common and widely distributed in the island. Described from specimens obtained by me on 23rd June 1929, at Takao. This robust species is characterised by the unusual shape of the median lobes.

Pinnaspis lithocarpi, sp. n. (fig. 4).

Adult female. *Scale* narrow, elongate, widened towards the posterior end, convex on the dorsum, sometimes somewhat curved, white, without ridges, about 2·0 mm. in length. The 1st larval skin pale yellowish brown, slightly extending

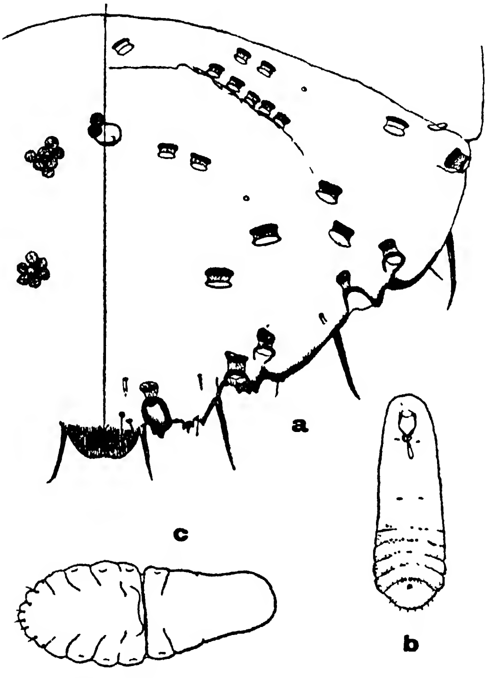

Fig. 4. *Pinnaspis lithocarpi*, sp. n.: *a*, pygidium of adult female; *b*, adult female; *c*, second larval skin.

beyond the anterior extremity of the 2nd. The 2nd larval skin yellowish brown, about 2·2–2·5 times as long as wide, a little shorter than the posterior secretion, about 0·8 mm. in length, with a distinct transverse furrow about the middle and 3 pairs of marginal spines on the pygidium. Secretion a little extending beyond the lateral margins of the posterior half of the 2nd larval skin.

Body narrow, elongate, somewhat widened towards the last free abdominal segment. Antennae with a long, stout, somewhat curved seta. Anterior spiracles with a parastigmatic pore, posterior spiracles lacking pores. Abdomen with many glands similar to those on the pygidium, lacking long spines; the last 4 segments well defined, protruding laterally; the last segment with a very small, conical, chitinised spine near the lateral margin.

Pygidium much wider than long, with 2 distinct indentations on each side, chitinised on the posterior margin. Anal opening nearer to the base. Dorsal glands very short, wider than long, distributed as shown in the figure, those on the anterior part smaller. Marginal glands 6 on each side. Circumgenital pores in 5 groups, the median group with 4 pores, the upper lateral with 7–10, the lower lateral with 7–10. Median lobes united, not serrate or notched, large, protruding; the 2nd lobes very small, pointed, notched. Gland spines long, much longer than the median lobes, not expanded at the base, 4 on each side.

Host. *Lithocarpus* sp., attacking the lower side of leaf.

Hab. Hori, Suisha.

Very common. Described from specimens taken by me on 23rd November 1929, at Suisha. Allied to *Pinnaspis chionaspiformis*, Newst., but differs in the shape of the median lobes.

Tsukushiaspis vermiformis, sp. n. (fig. 5).

Adult female. *Scale* long, very narrow, usually curved, nearly parallel-sided, convex on the dorsum, greyish white, with no ridges, about 1·5–2 mm. in length.

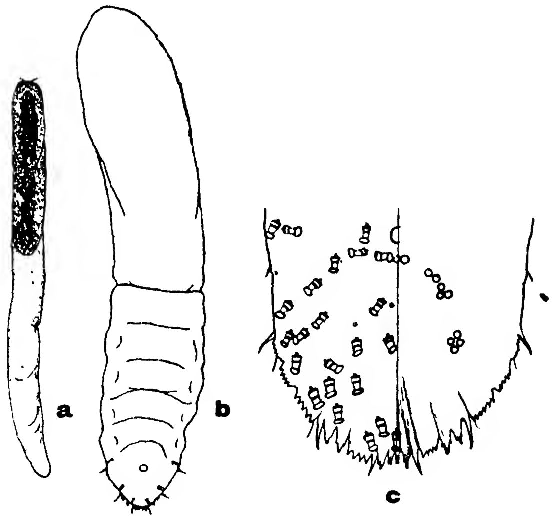

Fig. 5. *Tsukushiaspis vermiformis*, sp. n.: *a*, scale of adult female; *b*, second larval skin; *c*, pygidium of adult female.

The 1st larval skin a little extending beyond the anterior end of the 2nd, pale yellowish brown. The 2nd larval skin a little shorter than half the length of scale, narrow, long, somewhat curved, pale yellowish brown, about 0·7 mm. in length, with a distinct transverse furrow behind the middle and about five transverse furrows on the posterior part; pygidium with 3 marginal glands on each side. Secretion not extending beyond the lateral margins of the larval skins, with a few very small indentations on the side.

Body elongate, narrow, almost parallel on the sides, about 5 or 5·5 times as long as wide, about 1·1 mm. in length. Antennae more narrowly separated from each other than from the lateral margin of body, with a long stout seta and a much shorter one, the longer one slightly curved, a little shorter than the distance between the antennae. Anterior spiracles as long as or slightly shorter than the longer antennal seta, with 0–2 parastigmatic pores, posterior spiracles located about mid-length of body, equal in size to the anterior ones, without parastigmatic pores. Some minute

glands present behind the anterior spiracles. Abdomen with many small glands in a transverse group on the basal part, the last 3 segments more or less defined, not produced laterally, with many glands on the side, lacking gland spines ; the glands on abdomen similar to those on the pygidium.

Pygidium longer than wide, with many dorsal longitudinal wavy lines on the median area. Anal opening circular, near the base. Dorsal and marginal glands short, distributed as shown in the figure. Circumgenital pores smaller than the anal opening, almost equal in diameter to the dorsal glands, in 5 groups, the median group with about 4 pores in a row, the upper lateral with about 3–5, the lower lateral with about 4. Lobes equal in size, longer than wide, tapering, rather pointed apically, usually with a small notch on the side ; median lobes parallel ; 2 lateral lobes approximate to each other. A pair of bi- or trifurcated plates between the median lobes narrow, a wide furcated plate between the median and 2nd lobes, 3 similar plates outside of the last lobes ; these plates as long as or slightly shorter than the lobes. Gland spines longer than the lobes, 3 or 4 on the side.

Hosts. *Bambusa stenostachya*, *Bambusa* sp., *Dendrocalamus latiflorus*, attacking the lower side of leaf.

Hab. Taihoku, Tosei.

Very common, occurring in loose clusters. Described from specimens collected by me in February 1930. This species is allied to *Tsukushiaspis hikosani*, Kuw., differing in the shorter lobes, and is also closely related to *T. linearis*, Green, but is distinguished from it by the shape of the median furcated plates, as well as by the distribution of the dorsal gland orifices. The scale of this species closely resembles that of *T. neolinearis*, Takah.

Tsukushiaspis phragmitis, sp. n. (fig. 6).

Adult female. *Scale* very long, narrow, scarcely curved, not widened posteriorly, white, about 2·6 mm. in length. Larval skins yellowish brown ; the 1st larval skin

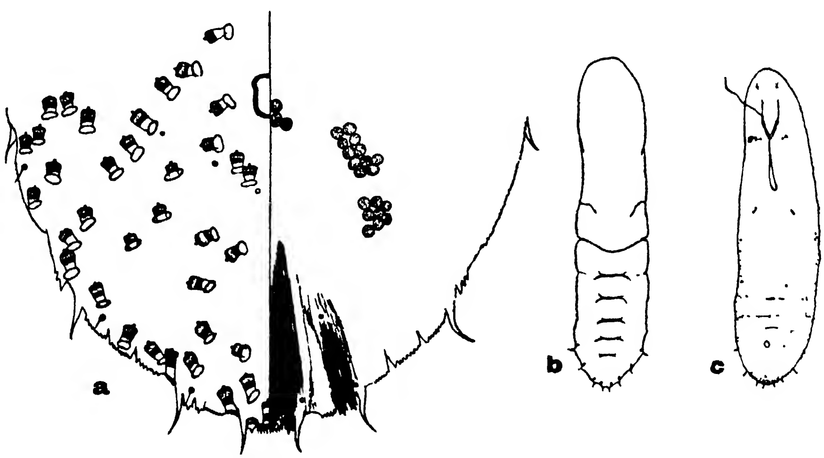

Fig 6. *Tsukushiaspis phragmitis*, sp. n. : *a*, pygidium of adult female ; *b*, second larval skin ; *c*, adult female.

on the anterior extremity of the scale ; the 2nd skin much shorter than half the length of scale, long, narrow, about 4·5 times as long as wide, about 0·9 mm. in length, with a distinct transverse furrow behind mid-length and about 5 transverse furrows on the posterior portion ; pygidium with 4 pairs of gland spines and 4 pairs of marginal

glands. Secretion occupying most of the scale, somewhat convex, not extending beyond the lateral margins of the larval skins, lacking ridges, with transverse striae on the posterior portion.

Body elongate, somewhat narrowed towards the front on the anterior half, broadly rounded at the posterior end, about 3·5–4·5 times as long as wide, about 0·9–1·05 mm. in length. Head with a few very minute setae. Antennae as far from each other as from the lateral margin of body, with 2 long curved setae, one of which is much longer and stouter, longer than the spiracles. Anterior spiracles with 2 or 3 parastigmatic pores in a loose group, posterior spiracles wanting pores. Abdomen with many glands on the lateral area, which are similar to those on the pygidium ; many similar but slightly smaller glands in a transverse group on the basal part ; many minute slender glands in a group behind the above-mentioned group ; the last three segments defined, scarcely protruding laterally, without spines.

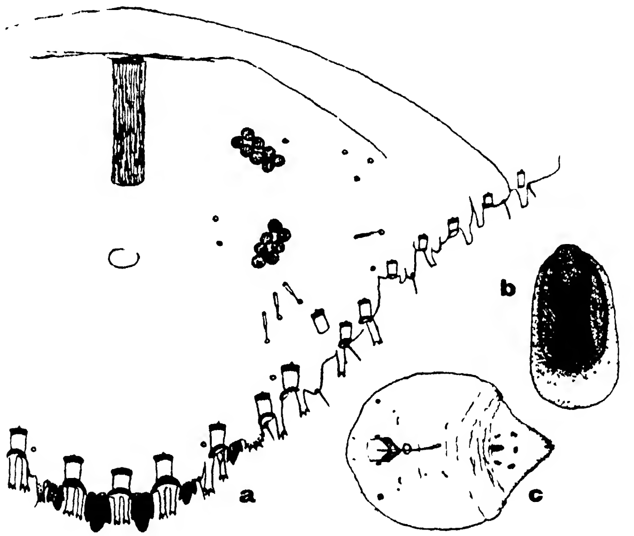

Fig. 7. *Parlatoria machili*, sp. n. : *a*, pygidium, and *b*, scale, of adult female ; *c*, adult female.

Pygidium wider than long, with many dorsal wavy lines. Anal opening chitinised on the margin, longitudinally oval, large, near the base. Dorsal gland orifices and marginal glands as shown in the accompanying figure. Circumgenital pores as large in diameter as the dorsal gland orifices, in 5 rather dense groups, the median group with about 3–5 pores, the upper lateral with 10 or 11, the lower lateral with about 8 or 9. Lobes very small, more or less pointed apically, almost equal in size, with a distinct notch on the side ; median lobes parallel, two lateral lobes approximate to each other. Furcated plates wide, very short, as long as the lobes, a pair between the median lobes, one between the median and the 2nd lobes, three outside of the last lobe, a small trifurcated plate on the side slightly protruding. Gland spines long, longer than the lobes, about 0·0095–0·013 mm. in length, 4 on each side.

Host. *Phragmites* sp., attacking the upper side of leaf.

Hab. Suo, Chippon, Daichikko near Daibu.

Very common at Suo. Described from specimens collected by me on 30th December 1924, at Suo. This species is characterised by the very short lobes and furcated plates.

Parlatoria machili, sp. n. (fig. 7).

Adult female. *Scale* oval, flattened, about 1·7 times as long as wide, about 1·0 mm. in length. The 1st larval skin pale yellowish brown, somewhat extending beyond the anterior extremity of the 2nd skin. The 2nd larval skin black on the median area, yellowish brown on the marginal area, sometimes broadly reddish brown on the posterior margin, about 1·7 times to twice as long as wide, occupying most of the scale, completely enveloping the body, about 0·8 mm. in length, pygidium with 6 small lobes and 14 very short marginal glands. Secretion grey, a little extending beyond the lateral margins of the larval skins.

Body: head and thorax with a few short setae on the marginal area. Eyes present, submarginal. Antennae with a long, stout, slightly curved seta and 4 very small spikes. Anterior spiracles with 3 parastigmatic pores, posterior spiracles as long as the anterior ones, without pores. Abdominal segments more or less defined, with some very small lateral glands, the last segments with some truncate gland spines.

Pygidium wider than long, tapering. Anal opening transversely oval, at the centre. Dorsal gland orifices wanting except one on the submarginal area on each side. Marginal glands short, with strongly chitinised openings, 21 in all, those on the basal part smaller. Circumgenital pores smaller in diameter than the median marginal gland, in 4 groups, the upper lateral group with 8 pores, the lower lateral with 6 or 7. Lobes 6 in all, with a notch on the side; median lobes large, broad, rounded at the tip, longer than wide, a little longer than the median processes; the 2nd lobes smaller, not divided, more or less rounded at the tip; the 3rd lobes the smallest, pointed apically. Processes slender, bi- or trifurcated (but those near the base truncate), 2 between the median lobes, 2 between the median and 2nd lobes, 2 or 3 between the 2nd and 3rd lobes, about 8 outside of the last lobes. A small furcated plate outside of the last lobe, approximate to it.

Host. Machilus spp., attacking usually the upper surface of the leaf.

Hab. Hokuto, Sozan, Taihoku.

Described from specimens taken by me on 26th April 1927, at Hokuto.

Allied to *Parlatoria aonidiformis*, Green, and its relatives, but differs in the characters of the pygidium (see the figure). The 2nd larval skin is unusually large, completely enveloping the body, as in *Fiorinia* and *Cryptoparlatoria*.

Fiorinia smilaceti, sp. n. (fig. 8).

Adult female. *Scale*: The 1st larval skin a little extending beyond the anterior extremity of the 2nd skin, pale yellowish brown. The 2nd larval skin thick, stout, curved, rounded on the front, black, pale brown on the margin and pygidium, about 0·85 mm. in length, with some small irregular indentations on the margin; pygidium with a short marginal spine near base, 5 marginal glands on each side, and very stout, large, serrate median lobes in an incision. No secretion extending out of the 2nd larval skin.

Body broadest about the middle, rather abruptly narrowing towards both ends, about 0·05 mm. in length, without glands or gland spines. Head without a tubercle between the antennae. Antennae near the front margin, with a long, very stout seta which is slightly curved, not pointed apically. Anterior spiracles as long as the antennal seta, with 2 parastigmatic pores, posterior spiracles a little shorter than the anterior, without parastigmatic pores.

Pygidium a little wider than long, with many wavy lines, lacking dorsal gland orifices. Anal opening near the base. Marginal glands slender, 5 on each side. Circumgenital pores much smaller than the anal opening, arranged nearly in a complete arch, the median group with about 7–9 pores in a single row, the upper lateral

with about 8, the lower lateral with about 14. Median lobes in a distinct incision, somewhat protruding, divergent, serrate on the margin, rounded apically, with a seta near the base; the 2nd lobes small, divided. Gland spines wanting, but about 5 long marginal setae present.

Host. *Smilax* sp., attacking the lower side of the leaf.

Hab. Shinten.

Many specimens were collected by me in January 1927. This species is characterised by the large median lobes of the 2nd larval skin.

Aonidia (Greeniella) lahoarei, sp. n. (fig. 9).

Adult female. *Scale* flattened, somewhat convex on the middle area of dorsum, mostly shining reddish black, yellowish brown on the marginal area except on the

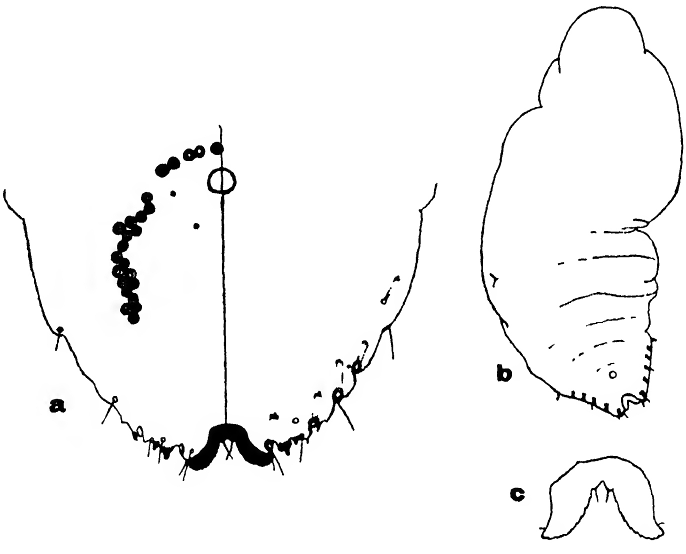

Fig. 8. *Fiorinia smilaceti*, sp n.: *a*, pygidium of adult female; *b*, second larval skin *c*, median lobes of second larval skin.

posterior projecting portion, very narrowly dusky on the margin, about 0·6 mm. in length. The 1st larval skin on the 2nd skin, not easily recognisable, a little longer than wide. The 2nd larval skin occupying most of the scale, circular or subcircular on the thoracic part, projecting posteriorly on the abdominal part, a little longer than wide, with many areolations on the marginal area and a distinct transverse furrow at the base of the projecting part; pygidium with 3 pairs of distinct lobes and many slender fimbriated squames equal in length. Secretion whitish, thin, slightly extending beyond the margin of the 2nd larval skin.

Body almost as in the 2nd larval skin in general shape, with the pygidium protruding, about 0·5 mm. in length. Antennae not placed close together, submarginal, with a long, stout, curved seta. Mouth-parts rather large. Spiracles lacking parastigmatic pores, posterior spiracles a little longer. Abdominal segments defined, with many minute glands on the side of basal segment; the last three segments not protruding laterally, without glands and spines.

Pygidium produced into a long median projection which is a little expanded basally, somewhat trilobed at the tip, not pointed, with 4 processes on each side; 3 pairs of slender, long processes on the hind margin, which are expanded at the base, equal in length, a little narrowed in the apical part, not sharply pointed, somewhat shorter than half the length of median projection, and longer than the processes on that projection; 3 very small, slender, truncate processes outside the above described processes on each side. Venter with many lines radiating from the genital opening to the lateral margin and some small circular pores on the submarginal area.

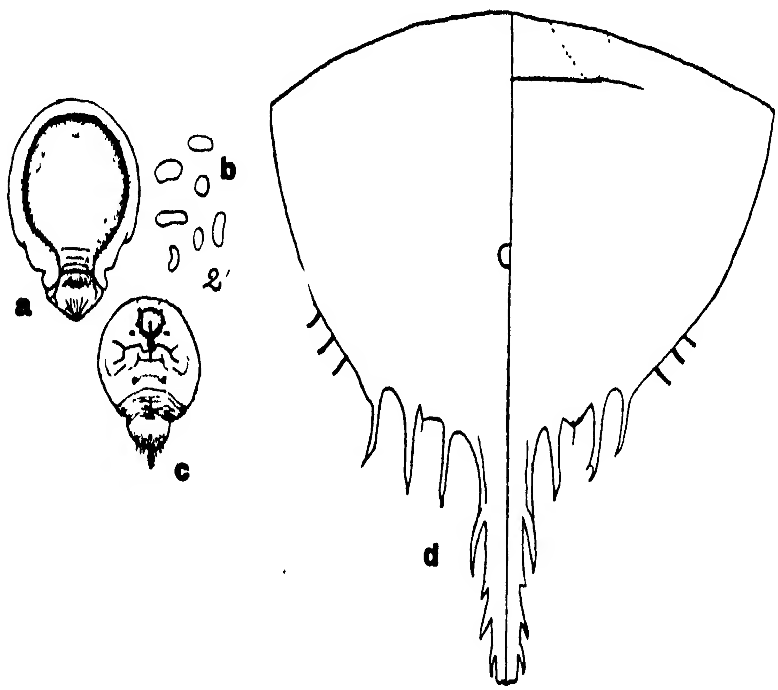

Fig. 9. *Aonidia lahoarei*, sp. n.: *a*, second larval skin; *b*, areolations on the second larval skin; *c*, adult female; *d*, pygidium of adult female.

Host. *Eugenia* sp., attacking the lower side of leaf.

Hab. Sozan, Suisha.

Described from specimens taken by me on 26th January 1930, at Suisha. This species is allied to *Aonidia tentaculata*, Green, but differs in the shape of pygidium. This species has been named after Lahoare, the famous chieftain of a savage village in Formosa, who is the last and only one to resist the Government of Formosa.

FURTHER NOTES ON THE FOOD-PLANTS OF NIGERIAN INSECTS.

By F. D. Golding, M.A., F.E.S.

In 1927 the writer published a paper entitled "Notes on the food-plants and habits of some Southern Nigerian Insects," compiled from observations made between 1922 and 1925; the present paper contains additional data obtained since 1925.

The writer wishes to acknowledge his indebtedness to the Imperial Institute of Entomology and the specialists of the Department of Entomology in the British Museum for identifying the insects mentioned.

LEPIDOPTERA.

Name.	Food-plants.	Part attacked.	Month of appearance.	Locality and remarks.
NYMPHALIDAE				
Acraea pharsalus, Ward	*Ficus asperifolia*	Leaves	Oct.	Ibadan.
ARCTIIDAE				
Diacrisia lutescens, Wlk.	*Zea mays*	,,	July	,,
NOCTUIDAE				
Anomis leona, Schaus	*Theobroma cacao*	Wall of young green pod	Aug.	,,
LYMANTRIIDAE				
Dasychira georgiana, Fawc.	*Arachis hypogaea*	Leaves	,,	,,
LASIOCAMPIDAE				
Trabala lamborni, B.B.	*Combretum bracteatum*	,,	June	,,
LIMACODIDAE				
Parasa urda, Druce	*Trema guineensis*	,,	Sept.	,,
Parasa viridissima, Holl.	*Theobroma cacao*	,,	Oct.	About 20 miles east of Ibadan.
	Cola acuminata	,,	July	Ibadan.
	Hura crepitans	,,	June & Sept.	,,

RHYNCHOTA.

Name.	Food-plants.	Part attacked.	Month of appearance.	Locality and remarks.
PENTATOMIDAE				
Coptosoma nubila, Germ.	*Cajanus indicus*	Stem	May	Ibadan. Adults only.
Brachyplatys testudo-nigra, de Geer	*Gliricidia* sp.	,,	Sept.	,, ,, ,,
Agaeus pavimentatus, Dist.	*Tecoma stans*	Flowers	May	,, ,, ,,
Phricodus hystrix, Germ.	*Sesamum indicum*	Green pods	Sept.	Ilorin. ,, ,,
Aspavia acuminata, Mont.	*Pennisetum spicatum*	Seeds	Oct.	,, ,, ,,
Veterna mimica, Dist.	*Sesamum indicum*	Green pods	Aug	,, ,, ,,
Acrosternum acutum, Dall.	*Pennisetum spicatum*	Seeds	Oct. to Dec.	Ilorin. Adults in Oct.; adults and nymphs in Nov. and Dec.

Name.	Food-plants.	Part attacked.	Month of appearance.	Locality and remarks.
Agonoscelis versicolor, F.	*Sesamum indicum*	Green pods	Aug.	Ilorin. Adults, eggs and nymphs seen.
	Pennisetum spicatum	Seeds	Nov., Dec.	Adults and nymphs.
	,, ,,	,,	Jan.	Adults only.
	Gossypium spp.	?	March	,, ,,
Nezara viridula, L.	*Gossypium* spp.	Bolls	Nov. to March	Ilorin. Nymphs seen in Dec., Jan.; adults seen each month.
	Pennisetum spicatum	Seeds	Nov., Dec.	Adults and nymphs.
	Sorghum vulgare	,,	Dec.	Adults only.
Piezodorus pallescens, Germ.	*Gossypium* spp.	Bolls	Dec. to March	Ilorin. Nymphs in Dec.; adults each month.
	Pennisetum spicatum	Seeds	Nov., Dec.	Adults and nymphs.
Halydicoris scoruba, Dall.	*Gossypium* spp.	Bolls	Nov. to March	Ilorin. Adults and nymphs.
	Pennisetum spicatum	Seeds	Nov., Dec.	Adults and nymphs.
	Sorghum vulgare	,,	Nov., Dec.	Nymphs only.
	Vigna sinensis	Pods	Dec.	Adults, eggs and nymphs.
	Zea mays	Cobs	Nov.	Adults only.
Macroraphis infuscata, Wlk. *Glypsus erubescens*, Dist. and *Afrius purpureus*, Westw.	These three species were found attacking larvae of the Chrysomelid beetle, *Mesoplatys cincta*, Oliv., on a legume		Sept.	Ilorin Adults only.
COREIDAE				
Mirperus torridus, Westw.	*Gossypium* spp.	Bolls	Dec. to March	Ilorin. Adults each month, nymphs in Jan. only.
	Pennisetum spicatum	Seeds	Nov. to Jan.	Adults and nymphs.
	Vigna sinensis	Pods	Dec.	Adults only.
	Sorghum vulgare	Seeds	Nov., Dec.	Adults and nymphs.
	Uraria picta	,,	Aug.	Adults only.
LYGAEIDAE				
Lygaeus rivularis, Germ.	*Gossypium* spp.	?	March	Ilorin. Adults only.
	Pennisetum spicatum	Seeds	Oct. to Dec.	Adults only in Oct., adults and nymphs in Nov., Dec.
	Sorghum vulgare		Nov.	Adults only.
Aspilocoryphus fasciativentris, St.	*Gossypium* spp.	?	Feb., March	Ilorin. Adults only.
	Pennisetum spicatum	Seeds	Oct. to Dec.	Adults only.
Chauliops rutherfordi, Dist.	*Dolichos* sp.	Leaves	July	Ibadan. Adults only.
Oxycarenus gossypinus.	*Abutilon zanzibaricum*	Green fruits	Aug.	,, ,, ,,
Oxycarenus dudgeoni, Dist.	*Hibiscus rostellatus*	,,	July	,, ,, ,,
CAPSIDAE				
Halticus tibialis, Reut.	*Arachis hypogaea*	Leaves	April to Aug.	Ibadan. Adults and nymphs.
	Ipomaea batatas	,,	July	Adults only.
	Triumfetta rhomboidea	,,	Aug.	,, ,,
	Gossypium vitifolium	,,	,,	Adults and nymphs.

Name.	Food-plants.	Part attacked.	Month of appearance.	Locality and remarks.
TINGIDAE				
Monanthia ornatella, St.	*Triumfetta rhomboidea*	Leaves	Aug.	Ibadan. Adults and nymphs.
CERCOPIDAE				
Ptyelus grossus, F.	*Cajanus indicus*	Stem	May	,, ,, ,,
APHIDAE				
Myzus persicae, Sulz.	*Sesamum indicum*	Young shoots	Aug.	Ilorin.
Aphis laburni, Kalt.	*Arachis hypogaea*	Shoots	May	,,
	Phaseolus lunatus	Leaves	June	Ibadan.
	COLEOPTERA.			
CETONIIDAE				
Stephanorrhina guttata, Oliv.	*Elaeis guineënsis*	Rotten trunk	Aug.	Benin City. Bred from larvae.
Coelorrhina chloropyga, Thoms.	,, ,,	,,	,,	,, ,, ,,
HALTICIDAE				
Haltica punctata, All.	*Gossypium vitifolium*	Leaves	Oct.	Ibadan. Adults only.
GALERUCIDAE				
Monolepta lineata, Karsch	*Phaseolus ? vulgaris*	,,	Nov.	,, ,, ,,
Barombia humeralis, Laboiss.	*Mucuna* sp.	,,	July	,, ,, ,,
	Dolichos sp.	,,	,,	,, ,, ,,
	Gossypium sp.	,,	,,	,, ,, ,,
	Arachis hypogaea	,,	,,	,, ,, ,,
	Desmodium velutinum	,,	,,	,, ,, ,,
	Phaseolus lunatus	,,	Nov.	,, ,, ,,
HISPIDAE				
Platypria luctuosa, Chap.	*Mucuna* sp.	,,	July	,, ,, ,,
CASSIDIDAE				
Aspidomorpha isparetta, Boh.	*Gossypium peruvianum*	,,	June	,, ,, ,,
LAMIIDAE				
Apomecyna latefasciata, Qued.	*Gloriosa superba*	,,	Aug.	,, ,, ,,
CURCULIONIDAE				
Mitophorus acerbus, Fst.	*Gossypium* spp.	,,	Sept.	Ilorin Adults only.
	Urena lobata	,,	Oct.	,, ,, ,,
	Sesamum indicum	,,	July	,, ,, ,,
	Mucuna sp.	,,	Aug., Oct., Dec.	,, ,, ,,
	Pennisetum spicatum	,,	Nov., Dec.	,, , ,,
	Amarantus caudatus	,,	Sept.	,, ,, ,,
Siderodactylus sagittarius, Oliv.	*Gossypium* spp.	,,	Sept.,	,, ,, ,,
	Sesamum indicum	,,	July	,, ,, ,,
	Pennisetum spicatum	,,	Nov., Dec.	,, ,, ,,
	Amarantus caudatus	,,	Sept.	,, ,, ,,

A CONTRIBUTION TO THE STUDY OF THE NATURAL CONTROL OF GORSE.

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The Biological Control of Gorse.

In order to investigate the possible means of controlling introduced plant pests, the course that has been considered advisable to follow has been that of a general biological survey of the particular species under its native conditions and, so far as is possible, a comparison between this and a similar survey in the country to which it has become introduced. Such a survey should include the following aspects :—

Germination of seed : Normal percentage germination, germination of fresh and old seed, dormancy, " hard " seed, effect of varying external conditions or previous treatment upon germination of hard seed (if present). Seed reserves in soil ; continuous or discontinuous germination.

Establishment of seedlings : Effect of grass, leaf debris, bare soil, etc. ; root development ; causes of mortality.

Flowering : Periods of flowering, number of flowers ; mode of pollination.

Seeds and dispersal : Number of seeds, manner of dispersal, mortality before germination.

Relation to plant communities.

Relation to climate and soil types.

Geographical distribution.

Relation to insects : Insects found on the plant at different seasons ; nature and extent of damage to vegetative parts, flowers and fruits.

This leads on to an intensive study of such insects as are found to cause considerable damage to the plant, with a view to ascertaining their suitability for shipment to the country into which the plant in question has become introduced. It will be realised that the introduction of a plant into a new country will, in most cases, be brought about by the transport of its seed, and that it will therefore be improbable that any of the phytophagous insects attached to the plant will also be introduced. The plant is therefore at a great advantage from the beginning of its establishment in the new habitat in being free from its normal insect enemies. The attempt to restore the natural balance between host-plant and parasites is one of the main lines of biological control investigations.

In connection with the Noxious Weed Control Project on behalf of the New Zealand Government, work has been started along these lines upon gorse (*Ulex europaeus*) and ragwort (*Senecio jacobaea*) at Farnham House Laboratory, and it is intended here to discuss the significance of certain facts that have appeared in connection with gorse.

General Information concerning Gorse.

The genus *Ulex* is confined to Western Europe and North Africa, except in so far as species have become introduced into other parts. There are twenty species, and of these three are native in Great Britain, viz., *Ulex europaeus*, L. (common gorse, furze, or whin), *Ulex gallii*, Planch. (western furze), and *Ulex minor*, Roth. (small or dwarf furze). The last two are, in older literature, regarded as one species, *Ulex nanus*, Forst., which name is still often applied to the dwarf furze.

These three British species are to be distinguished as follows :—

	Calyx	Bracts	Petals	Number of ovules	Average no. of seeds	Months of flowering	Months of ripe seed
U. europaeus ...	Hairy	1/12″	Wing > keel	14	3–8	12–6	6–10
U. gallii ...	Nearly glabrous	Very small	Wing < keel	4–6	2	7–11	5–7
U. minor ...	,,	,,	Wing < keel	5	2	7–11	5–7

While *U. europaeus* is distributed generally throughout the British Isles, *U. gallii* is confined to Ireland, Wales and the West of England, and *U. minor* is confined to the South and East of England. Intermediate forms between *U. gallii* and *U. minor* are common where the zones of these two overlap and a form, believed to be a hybrid between *U. europaeus* and *U. gallii*, occurs in the Malvern Hills.

The Yearly Cycle of U. europaeus in the South.

During the winter the bushes appear very brown owing to the death of most of the spring shoots ; in this condition flowering takes place. It may begin in an indifferent manner as early as September or October, but the flowers which appear before April do not produce fruit except on very occasional bushes. No insects have been observed visiting winter flowers and the pollination mechanism releases itself without external agents. It is doubtful whether the pollen is active at this period.

The maximum period of flowering is reached near the middle of April, and the majority of these flowers produce fertile pods. Bees visit the previously unopened flowers more than do any other insects, and one of the gorse weevils, *Apion ulicis*, which has been hibernating on the branches, now becomes very active and vigorously devours the petals, often flying from flower to flower on the hotter and more sunny days.

The new shoots for the year now start growing from the buds. Flowering comes to an end very suddenly early in June, and pods start dehiscing toward the end of June or early in July. In damp places or in damp years dehiscence of some pods may be delayed well into the autumn, and in Scotland unopened pods containing good seed are obtainable as late as the following February.

Germination of seed takes place under suitable conditions at any time of the year, this irregularity being largely due to the high percentage of hard or impermeable seeds.

Old bushes are often to be found which have apparently died or are just about to die of old age. Sections have been taken near the base of several of such bushes, growing in different parts and under different conditions, and in all cases the number of annual rings has been between 23 and 30, indicating that it is probable that gorse never grows older than 30 years. In this connection it must be remembered that in large gorse areas, where the aerial shoots are at times cut or burnt down, the root systems are likely to be very much older than the shoot systems, which readily spring up from the stumps of cut bushes or of burnt bushes, if not too heavily burnt over.

Spread by adventitious Rooting.

It has been found that, on light soils at least, the procumbent branches of gorse may send out adventitious roots into the earth, thus rendering these branches less dependent upon the original root system. This has been observed at Wheelerend Common, Bucks, and especially where the procumbent branches have become overgrown by grasses.

Where gorse grows on shingle, as at Rye, Sussex, the lower branches tend to creep horizontally along just below the surface of the shingle. These branches commonly bear numerous adventitious roots 0·5 to 5 cm. long, with nodules, and large roots frequently anchor them to the ground.

The Calcifuge Habit.

While the older conception of this term envisaged the inability of a plant, in virtue of its physiological organisation, to grow in calcareous soils, the more modern conception is much modified. It has, for instance, been shown that many, and probably most, so-called calcifuge plants are able, in the absence of competition as in the garden flower-bed, to grow in highly calcareous soils. With this conception in view, *U. europaeus* may rightly be described as calcifuge, as it is found to flourish on all kinds of non-calcareous soils, but only rarely on highly calcareous soil, and then probably always as a result of artificial interference with the competitive factors.

In the chalk districts of the S.E. of England gorse may be frequently found occupying large areas of common land, especially on the hill-tops, but such areas are invariably associated with caps of sand, gravel or clays overlying the chalk. Moreover, in certain parts of the Chilterns where such caps of soil terminate on a hillside there is a marked change from gorse to juniper scrub, coinciding with the change from gravel, etc., to chalk. Nevertheless, in the same district several cases have been seen where large flowering bushes of gorse grew healthily on almost pure chalk, accompanied by numerous seedlings of less healthy appearance. These are always in places where artificial interference has occurred. One was a roadside embankment, probably ten years old, and another was a chalk quarry becoming re-vegetated. Exceptionally large nodules have been found in such soils.

Experiments have been carried out to test the effect of acid and calcareous soils on the germination of scratched seed and the development of seedlings. The results showed that the percentage germination is lower in the calcareous soil, and growth generally, whether measured by size or by dry weight, is very much less pronounced in the calcareous soil, except in one respect, namely, that in the earlier stages of development the calcareous soil induces a better development of roots.

Germination Experiments.

In a series of germination tests carried out, 50 per cent. of untreated seeds had germinated by the 70th to the 130th day, and after this time further germinations were infrequent, only another 10 per cent. having germinated by the 214th day. Scratched seeds all germinated by the 12th day, the " hard " seed factor being thereby eliminated ; but under the same conditions only 25 per cent. of the unscratched seeds had germinated by the 12th day. This indicates that the germination of some 75 per cent. of the seeds is delayed to varying extents through "hardness," and that another 25 per cent. become permeable and germinate within about 16 weeks, while some 35–40 per cent. remain " hard " for a time at present undetermined, but exceeding one year.

A moderate percentage of hard seed may be of value to a species, especially such as gorse, which is subject to considerable interference by man and animals, in so far as it ensures a supply of seed in the ground, of which a fraction will become available for germination at any time for a number of years when suitable conditions obtain. For this reason, the burning over of a gorse area in two or three successive years is not likely to free the area from further growth of gorse. Indeed, there is little doubt that burning renders a number of " hard " seeds permeable, so that, provided they are not so near the surface of the earth as to be killed by the heat, a further quantity is immediately available for colonising the bared ground.

It is not known how long the "hard" seeds remain alive and capable of germination, nor is it known by what process in nature the seed coat is eventually rendered permeable. In *Nature*, for 26th September 1918, it is recorded that certain land in Cumberland was cleared of gorse and heather in 1893. After 25 years the land, which had been during that time under permanent pasture, was ploughed and recultivated, and gorse seedlings appeared.

The effect of high temperatures on the permeability of the seed-coats has been seen in germination experiments in the laboratory and in the field. Subjection of the seeds to hot air or hot water for five minutes increases the number of seeds that germinate in any given period, but if the temperature reaches 80° C., the early germinations are delayed by a few days.

In this connection an interesting observation was made on Gerrards Cross Common, Bucks; an area of gorse was so heavily burnt over in October 1929 that no vegetation was left alive. By December a quantity of gorse seedlings had appeared, and more seeds had germinated by January. Scarcely any further germinations had taken place up to April, except upon an area where a heap of charred wood had been burnt early in March; there a great number of new seedlings had appeared, although no fresh seed had fallen on the ground, nor had the surface been disturbed. The explanation is clearly that all permeable seeds near enough to the surface had already germinated, but the high temperatures had rendered a quantity of previously "hard" seed permeable.

Since areas of gorse in the country are frequently burnt over, intentionally or accidentally, the effect of heat upon the permeability of the seed would appear to be a factor of no little ecological importance.

Dispersal of Seed.

Dispersal of seed up to two or three feet from the parent bush may take place as a result of the explosive manner in which the pods dehisce. The seeds have at one side an oil-containing appendage known as the aril, and this structure is said to be sought after by ants, which may carry away the whole seed in order to eat the aril at leisure. This view is held by Weiss, who showed that ants would take away seeds placed in their track and claimed that the invasion of certain heather moors by gorse in parts of Yorkshire is due to this action of ants. Dispersal by ants has not been directly observed in the present investigation.

The quantity of seed in the ground under gorse bushes is extraordinarily variable, a series of counts in plots one foot square and down to two inches depth having yielded results varying from 4 to 1,000 to a square foot. The low values are associated with close-turfed plots, below the surface of which the seeds could not penetrate. Seeds lying on such a surface would be easily found by birds, ants, etc. The higher values relate to plots in loose gorse or bracken debris, in which a fallen seed may penetrate immediately some little way and be further covered up by subsequent accretion of the debris from the bushes in autumn and winter.

In plots laid down three feet away from gorse bushes very few seeds have been found, two or three to a square foot, and none have been found in plots five feet from the bushes.

Establishment of Seedlings and Causes of Mortality.

Studies of the appearance, establishment, and fate of seedlings have been made on various plots kept under periodic observation. These plots were laid out under a variety of conditions: under overhanging gorse, where gorse was recently cut,

where recently burnt, where competition with grasses, etc., occurred in previously burnt or cut areas and on an artificially bared soil.

The following is a summary of the causes of mortality during the ten months from June 1929 of 851 seedlings under observation :

Eaten by rabbits, etc.	71
Pulled or scratched out by birds, etc.	16
Choked by grass	8
Dried up	221

During the summer of 1929 these germinated during a brief moist period followed by a prolonged drought.

Rotted owing to water-logged soil during winter	54
Improperly rooted, owing to germination on surface of compact soil	12
Missing	85
Remaining alive	384

These figures give at least some indication of the nature of the adverse factors met with by gorse seedlings during their struggle for survival.

The effect of the eating off of the tops of young plants varies according to whether the plants are growing in otherwise bare ground or in competition with grasses, etc. When the base of the shoot is unshaded by other plants, the eating off of the top, or even all but the lowest inch or two, stimulates the lower buds to develop, and a more bushy plant results. But when the plants are surrounded by grasses, the lower buds appear to be unable to shoot out and the plant frequently dies. Thus many of the plants, the death of which is attributed above to their being eaten by rabbits, would not have died in the absence of competition with grasses. The deaths attributed to choking by grasses are all cases where no nibbling had taken place, the grasses being *Agrostis vulgaris*, *Deschampsia flexuosa*, or *Holcus lanatus*.

It is uncommon to see gorse seedlings developing in any closed community of plants except where grass is closely grazed and the soil thus more or less exposed. It would seem very probable that if gorse is actually spreading in New Zealand on to farm land, it is mainly on the somewhat over-grazed and poorer hill pastures.

Seedling gorse is better able to establish itself after burning of an area than after the old gorse has been cut down, because in the latter case the accumulated debris is usually so deep that, under summer conditions, the roots seldom reach mineral soil before they have dried up; whereas the burning of the debris brings the mineral soil to the surface as well as having the effect upon the seeds described above.

In the colonisation of bared ground there are two sources of renewed vegetation—seed, and shoots from the cut or burnt stumps. The majority of burnings leave the stumps alive with buds capable of shooting out from the base, though a heavy burning may kill everything. If the fire is proceeding against the wind it passes more slowly over a given area and is usually far more destructive than if blown rapidly across it with the wind.

The growth of these basal shoots from the stumps is, during the first two years, about two and a half times as great as that of the seedlings, so that where competition between the two occurs the seedlings are usually almost entirely choked out by the vegetative shoots.

In order, therefore, to destroy a patch of gorse completely by burning, it is necessary either to burn it so intensively that everything is killed, or if this is impossible, to burn it over in successive years until the food reserves in the roots are exhausted. It is not yet known how soon this would take place, but it is likely that two or three years would be sufficient.

By turning sheep or goats on to such an area the subsequent burnings, after the first one, might be dispensed with, as the animals would perform the same function and in addition would check the development of seedlings.

It is probable that much could be done to eliminate undesirable areas of gorse by a systematic combination of burning and grazing.

Damage by Insects.

The damage done to the vegetative parts of the plant appears to be of little importance. It is mostly the piercing of the cuticle and sucking out of the mesophyll or sap by *Apion ulicis*, Capsid bugs and possibly a few other insects. One or two Lepidopterous larvae spin up the ends of the young shoots, and when they eat out the growing points, as does *Anarsia spartiella*, the damage done is of more importance.

It is to the flowers and to the pods that the greatest amount of damage is done, and except for *Apion ulicis*, almost all of this is due to Lepidopterous larvae. The flowers are not attacked before April, and then only when hot weather sets in. The first insect to become active in this respect is *Apion ulicis*, which, rousing itself from its lethargic winter condition, runs about the shoots and eats out portions of the petals, leaving small perforations. On the hotter and more sunny days it may be seen flying from flower to flower. Similar damage to the petals is done by *Sitones* spp., except that these weevils eat the petals from the margin, leaving them with irregular outlines instead of with perforations. This kind of damage is not very harmful to the plant since the petals have no essential function, but only help to attract insect visitors.

During May, however, a whitish caterpillar (unidentified) appears in the flowers and eats out the ovaries and anthers, thus preventing the formation of fruit and seed from those flowers. This larva is found to be very widespread and counts of damaged flowers were made out of a few hundred open flowers selected at random from several districts. The unopened buds were not attacked.

Date	Locality	Flowers examined	Eaten	Per cent	Larvae found	Remarks
9.v.30	Cadmore End, Bucks	200	9	4·5	—	—
14.v.30	Stoke, Bucks	500	8	1·6	3	Of 100 flowers which fell into net on beating 57 were eaten out and 8 larvae found.
14.v.30	Gerrards Cross	500	70	14·0	33	—
16–26.v.30	Luccombe, Somerset	400	6	1·5	3	—
	Selworthy, Somerset	200	1	0·5	—	No larvae in flowers beaten off.
	Countisbury Hill, Lynton, Devon	500	13	2·6	10	—
	Ilfracombe, Devon	200	5	2·6	3	—
	Mortehoe, Devon	400	26	6·5	17	—
	Roburgh, Devon	400	20	5·0	6	—
5.vi.30	Gerrards Cross	500	61	12·2	—	Only few flowers left and damage partly due to *Anarsia spartiella*.

N.B.—Damaged flowers tend to occur in groups of 2 or 3, probably owing to one larva attacking adjacent flowers.

This larva disappears very suddenly about the end of May, and no pupae were obtained. It is followed, at least on the Commons near Farnham Royal, by a phase of *Anarsia spartiella* and a number of other larvae doing similar damage but of less frequent occurrence; those that have so far been reared to adult stage and identified are *Depressaria costosa* and *Pseudoterpna pruinata*.

Anarsia spartiella was found in flowers from 15.v.30 to 5.vi.30 at Gerrards Cross and Stoke, Bucks, and from 1.vi.30 to 13.vi.30 it was found to have migrated, following the cessation of the flowering period, to the tips of the young shoots, spinning them round itself and eating out the growing points in such a way that the dead severed spines remained held together around the larva. In this condition it was found at Gerrards Cross, Stoke, Rye, Sussex, and Ashdown Forest, Sussex. It was also found in the shoot tips of *U. minor* at Gerrards Cross.

It was found to be heavily parasitised while in the tips of the shoots and by 13.vi.30 only dead or parasitised larvae were obtainable. The following parasites were found at Gerrards Cross :—

(1) *Paralitomastix varicornis*. An internal larval parasite—from 30 to 60 developing within each larva. These emerged in the laboratory between 3.vii.30 and 18.vii.30.

(2) *Pimpla inquisitor*.

(3) *Pimpla detrita*. External larval parasites—1 to 3 feeding on each larva; emerged from pupa in the laboratory 5.vii.30.

(4) *Microbracon stabilis*. An external larval parasite; emerged from pupa in the laboratory 9.vii.30.

(5) (*Unidentified*.) External parasites which died before pupation; different from above.

(6) *Phaeogenes* sp. Pupal parasite; emerged in laboratory from 27.vi.30 to 6.vii.30.

A few pupae were found in the apices of the stems, but the majority probably fall to the ground. The larvae readily pupate on twigs kept indoors. The adults emerged from 28.vi.30 to 10.vii.30 in the laboratory.

Depressaria costosa was only found in the flowers, while *Pseudoterpna pruinata* was found eating out flowers and young shoots.

Damage to pods: The insects that have been found damaging pods are *Apion ulicis*, and two Microlepidoptera, *Laspeyresia ulicitana* and *Coleophora albicosta*. The life-cycle of *Apion ulicis* has been worked out by Maldwyn Davies (Annals of Applied Biology, xv, no. 2, 1928, pp. 263–286), who also gave some estimate of the amount of damage and of the distribution.

L. ulicitana is first to be seen flying around gorse bushes early in May. The larvae appear in the pods about 12th June, and examination of these recently infested pods showed evidence that the eggs had been laid on the surface of the pod and that the newly hatched larva had bored its way through the pod. By the beginning of July larvae are common in the pods, eating out the seeds, but by 10th July about 50 per cent. of the infested pods at Gerrards Cross, etc., had been left by the larvae, which when fully fed bore their way out of the pod and apparently fall to the ground, there to pupate. A recorded second generation, the larvae of which are found in September and October, has not been observed yet, but is probably on *U. minor* or *U. gallii*.

No area of gorse has yet been found in Great Britain free from *L. ulicitana*, and it is therefore clearly more widespread than is *Apion ulicis*, which is absent from many gorse areas in Devon, Somerset and all but the milder parts of Scotland.

Coleophora albicosta probably behaves similarly to *L. ulicitana* in its early stages and does similar damage in eating out the seeds, but the larva hibernates in pods or cases made of pods or sepals ; these cases are readily made if the larvae are kept in tins with suitable materials.

The following tables show the extent of damage by these seed-eaters. The figures for Lepidopterous larvae include *L. ulicitana* and *C. albicosta*, these two not having been distinguished at the time the records were made, but the latter is much less common than the former :—

Pod Infestation—Scotland.

Place	Scotston Moor, Aberdeen	Balgownie, Aberdeen	Invergordon	Hazelhead, Aberdeen	Lossie-mouth Cemetery
Date	30.ix.30	6.x.29	19.x.29	20.i.30	16.x.29
Total pods ...	300	300	300	100	275
Intact pods ...	247	210	206	99	196
Seeds in pods ...	728	706	763	352	806
Average no. of seeds per pod ...	2·94	3·36	3·7	3·5	4·1
Potential seed crop	882	1008	1110	355·5	1127·5
Infested pods ...	53—L	90—L	94—L	1—L	79*
Good seed in pods	13	27	16	0	14
No. seeds lost ...	143	275	348	3·5	319·8
Per cent. mortality	16·2	27·3	31·3	1	28·6
	Low scrubby bushes—open situation	Large spreading bushes 10 ft. high on slope of damp field sheltered by trees all round	Isolated bushes E. of town in field above shore and along shore		

* *Analysis of the* 79 *infested pods.*

L.	A.	L & A	M.
34	38	2	5
7	3	4	0
143·5	159·9	—	20·5
12·7	14·1	—	1·8
a	*b*		

L = Lepidopterous larvae; A = *Apion ulicis;* M = Mould.
a = 1 large orange larva; *b* = 100 *Apion* (35 grubs), 2 parasites.

Infestation of pods in Bucks. 9.vii.30. Pods both green and ripe collected from Stoke, Gerrards Cross and Burnham Beeches, and 200 of each opened and examined.

	Green pods	Ripe pods	Total
Gerrards Cross :—			
Good pods	134	175	309
Pods with *Apion* or parasite only...	62	19	81
Pods with caterpillars in ...	4	4	8
Pods from which caterpillars have left	0	2	2
} plus *Apion* ...	0	0	0
	200	200	400
Stoke —			
Good pods	51	75	126
With *Apion* or parasite only	132	96	228
With caterpillars in	9	11	20
From which caterpillars have left	8	18	26
} plus *Apion* ...	2	0	2
	200	200	400
Burnham Beeches :—			
Good pods	76	82	158
With *Apion* or parasite only	62	43	105
With caterpillars in ...	30	38	68
From which caterpillars have left	32	37	69
} plus *Apion* ...	8	4	12
	200	200	400

The separation of green pods from ripe pods shows the tendency of *Apion* to attack the later pods, *i.e.*, those which are youngest and softest at the time of oviposition. This is more striking in the case of an area of gorse at Pett, Sussex, where *Apion* was abundant but where an exceptionally early crop of pods completely escaped infestation. These pods were quite ripe by 22.iv.30, and by 10.vi.30 they had all dehisced and the newer crop, though of full size, was not yet ripe when examined.

	22 iv.30	10.vi.30
No. of pods examined	100	100
No. of pods with *Apion*	0	14 (11 with larvae and 3 with eggs)
No. of pods with *Laspeyresia* ...	0	2
Total per cent. infestation ...	0	16

Damage to Pods of U. minor and U. gallii.

As many of the insects feeding on *U. europaeus* also feed on *U. minor* and *U. gallii*, it is probable that any evidence of damage done to these other species will be of significance.

Pods of *U. minor* have been examined from Stoke and Gerrards Cross :—

	1.v.30, Stoke	14.v.30, Gerrards Cross	13.vi.30, Gerrards Cross	13.vi.30, Stoke
Pods examined	100	100	100	100
Pods infested	0	7 L	5 L	1 L

(L = Lepidopterous larvae unidentified.)

In the case of *U. gallii* all areas visited have shown a considerable infestation by one species of Lepidopterous larvae (unidentified), and no pods were damaged by any other insect.

18–26.v.30. 250 pods examined from each locality.

Locality	Pods eaten out	Per cent. destruction
Selworthy, Somerset	57	22·8
Welsford Moor, Devon	31	12·4
Bodmin Moor	56	22·4
Roburgh, Devon	13	5·2
Countisbury Hill, Lynton, Devon	33	13·2
Bude, Cornwall	13	5·2
Mis Tor, Dartmoor	31	12·4
Near Moor Gate, Dartmoor	5	2·0
Peak Hill, Sidmouth	4	1·6
Average	—	10·8

Other Insects of Possible Importance.

Apion scutellare is to be found on all species of *Ulex*, but is more abundant on *U. minor* and *U. gallii*. No area of *U. gallii* has yet been found without it. Its life-history is not known, and although it is said to form galls on the stems of *Ulex*, these have not been observed.

Asphondylia ulicis forms galls on the flower-buds or the young pods ; but 1930 was a bad year for this insect, and only one gall was seen. In 1929 it was fairly abundant and heavily parasitised.

Control Measures.

Up to the present the only insect which has been shipped to New Zealand for the purposes of control investigations is *Apion ulicis*. Of this over 100,000 have been sent out during the last year. Most of these were sent in cool store, but one shipment was made on a living gorse bush in a gauze cage. In spite of many precautions this method was unsuccessful, and both *Apion* and gorse died on the way.

It appears that although gorse is scheduled as a noxious weed in New Zealand, there is no desire to exterminate it, if this were possible ; on the contrary, it is much used for hedge-making. What is needed is some check to seed production, which, it is supposed, would make possible the artificial destruction of the plants in areas of poor grazing land where it has now become established, and at the same time prevent future re-establishment by dispersal of seed from other areas.

There is little doubt that so far as the checking of seed is the aim, the work is being carried out along the right lines. Although *A. ulicis* has not been induced to breed satisfactorily in New Zealand, there is still hope of its establishment there, and in addition there are several flower and seed-eating insects, such as *L. ulicitana*, *Coleophora albicosta*, *Anarsia spartiella*, and *Depressaria costosa*, which would appear to be very promising from this point of view. Their life-cycles need working out, and if, after satisfactory starvation tests, they are given a trial, it seems very probable

that some of them will do useful work after establishment in New Zealand. It is possible that the failure of *Apion ulicis* to breed satisfactorily in New Zealand may be in some way connected with the change over of seasons involved in travelling to the opposite hemisphere. It is suggested that this would be a more easily surmountable problem to an insect such as *Laspeyresia ulicitana*, of which there are two generations seasonally opposed to one another. Further, it would seem that a comparative study of the natural geographical distribution of the pest plant and of its various parasites would yield valuable suggestions as to the adaptability of the parasites to conditions in the country of introduction. For example, a parasite which is distributed as widely as its host-plant will clearly be more likely to establish itself in a large area of varied climatic conditions, than one which only occurs over a limited part of the area occupied by the host, provided that such limitation is due to climatic conditions, as it is most likely to be, rather than to competition with other parasites of the host or of itself.

But it has further to be considered how useful such checking of the seed supply will be when achieved. In the course of this work it has been shown that the ground beneath gorse bushes is usually well supplied with seed and that there is a high percentage of hard seed in it. This may become permeable and germinate at any time during a number of years, the maximum period not being known. Further, the seed of gorse is heavy seed and is not dispersed by the wind in falling, nor is the extent of dispersal by animal agencies, such as ants, at all well established. Consequently, any crop of seed that may be produced, however small in amount, will go to maintain the store in the ground. In the case of a plant with wind-dispersed seed, such as ragwort, the chances of any one seed finding suitable conditions for germination are so remote that any checking of the seed output must have a marked effect upon the future abundance of the species; but in the case of such a plant as gorse a complete absence of seed production for a few years would not be likely to have any marked effect upon the abundance of the species. It is true that if such a condition was achievable and was maintained for a number of years the species must eventually die out, since vegetative reproduction is not well enough developed for the habitual production of new plants. But if there were only a diminution of seed output by about 80 to 95 per cent., and more could not well be expected, then it is believed that no advantageous results would ensue and that it would merely reduce the number of seedlings which would die each year, either for want of suitable conditions beneath the parent bushes, or, if the latter were cleared away, as a result of competition among themselves. The plot work has not been carried far enough to show the inevitable mortality due to competition for space, but of the plants that now remain alive on all the plots there is an average population of 20 to a square foot. When the plots are covered by fully grown bushes, the population must be less than 0·25 to a square foot.

It is possible that in New Zealand there may be some far more effective agent of dispersal than we know of in this country. If the seed is regularly carried about in considerable quantities by some animal, then the conditions approach more to those of a highly dispersed seed, and a check to seed output would be reflected as a check in the population of the species, or at least in the rate of increase of the population of the species. It has been suggested that the Californian quail, another introduction into New Zealand, may perform this function, but no definite evidence has been produced; on the contrary, it has been stated that seeds eaten by this bird are ground up before being passed out. This is one of the many points which emphasise the importance of some biological survey of the host-plant being carried out in the country into which it has been introduced, as well as in its native areas.

The author wishes to expresses his thanks for kind advice and interest in the work to Dr. W. R. Thompson and to Dr. A. S. Watt, who also initiated several of the lines of work referred to in this paper.

NOTES ON THE LARVAE OF SOME SOUTH AFRICAN ANOPHELINES.

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The Grouping of the Larvae of South African Anophelines.

Puri[9] has divided the Indian Anopheline larvae into two divisions and four groups according to the character of the pleural hairs. The following is a study of the larvae of some South African Anophelines on the same lines.

Subgenus *Anopheles*, Christophers.

The larvae of this subgenus come into Puri's division A, which he defines as follows: Distance between the bases of the inner anterior clypeal hairs never more than one-sixth the length of one hair.

The only South African Anopheline belonging to this subgenus is *A. mauritianus*, Gpr. & Charm. The larva agrees very well with Puri's definition. The pleural hairs are all simple except the posterior ventral of the metathorax.

Subgenus *Myzomyia* (Blanchard), Christophers.

This is division B of Puri in which the inner clypeal hairs are widely separated, the distance between the bases never being less than one-quarter the length of one hair.

Group *Myzomyia*, Christophers. (Group 1 of Puri.)

The South African species which on adult characters fall into the *Myzomyia* group of Christophers are as follows:—*A. rhodesiensis*, Theo., *A. nili*, Theo., *A. cinereus*, Theo., *A. funestus*, Giles, *A. transvaalensis*, Carter, *A. longipalpis*, Theo., and *A. marshalli*, Theo.

The larvae of all these were examined, and only those of *A. funestus*, *A. marshalli* (Eastern Transvaal specimens, the larva of which has been described by the author[3]), and *A. longipalpis*, agree with Puri's definition of Group 1. The larvae of *A. rhodesiensis* and *A. transvaalensis* are intermediate between this group and Group 2 in that the anterior dorsal pleural hair of the mesothorax is feathered instead of being simple. From Group 2 they differ in having the anterior ventral pleural hair of the metathorax simple. These two larvae therefore agree with that of *A. sergenti*, which Puri also found to be intermediate. It is interesting to note that Puri found the larvae of the Indian form of *A. rhodesiensis** to be typical members of Group 1. This character exhibited by the larva of *A. transvaalensis* has been found to be of use in separating it from the closely allied larva of *A. marshalli*. Hitherto the author has relied on the structure of the lateral hair of the saddle, which is usually shorter and much branched in the larvae of *A. marshalli*, and longer and usually only bifid in that of *A. transvaalensis*.

The larva of *A. cinereus* resembles that of *A. turkhudi* as described and figured by Puri, except that the posterior dorsal of the metathorax is present as a minute simple hair. It differs from all other South African larvae in having both the anterior dorsal and ventral of the mesothorax with secondary branches, the ventral being less branched than the dorsal. The pleural hairs too are relatively shorter and stouter. The character of the pleural hairs gives an excellent means for the separation of this larva from that of some other nearly related species.

The larva of *A. nili* differs from all other larvae examined and also from any described by Puri. In the first place, the inner anterior clypeal hairs are very close together; though not so close as in the larva of *A. mauritianus*, the distance between

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* Christophers (*in litt.*) has given reasons for believing that the Indian and Arabian form of *A. rhodesiensis* is a distinct species from the African, and proposes to call it *A. d'thali*, Patton (F. W. Edwards).

their bases is nevertheless only one-fifth of their length, and sometimes it is less, Puri's division of the subgenera *Anopheles* and *Myzomyia* on this character therefore appears to break down. It further differs from all other larvae examined in the development of the posterior ventral hair of the prothorax. This hair is short, stiff, stout, heavily chitinised and with a few lateral barbs (fig. 1). In other respects the larva apparently resembles those of the *Neomyzomyia* group, except that the anterior

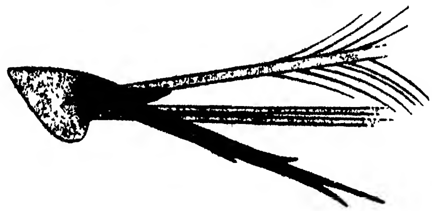

Fig. 1. *Anopheles nili*, the prothoracic pleural hairs of the larva.

dorsal of the prothorax is feathered and not simple. Too much stress cannot be laid on this latter feature, since it is found that even in typical *Neomyzomyia*, like *A. natalensis* and *A. ardensis*, the anterior dorsal, though not feathered, is nevertheless branched. It therefore seems advisable to regard *A. nili* as a modified *Neomyzomyia.*

Groups *Neocellia* and *Cellia*, Christophers. (Group 2 of Puri.)

The species belonging to these groups of Christophers are as follows .—

Group *Cellia*: *A. pharoensis*, Theo., *A. squamosus*, Theo., *A. argenteolobatus*, Gough, *A. jacobi*, Hill & Haydon.

Group *Neocellia*: *A. rufipes*, Gough, *A. theileri*, Edw., *A. pretoriensis*, Theo., *A. maculipalpis*, Giles.

The larva of *A. squamosus* was the only *Cellia* examined. This appeared to agree with Puri's Group 2, except that the anterior dorsal pleural hair of the mesothorax may be simple instead of being sparsely feathered.

The larvae of all the *Neocellia* were examined, and all, with the exception of the larva of *A. theileri*, belong to Puri's Group 2. The larva of *A. theileri* is a typical *Myzomyia* and the adult, too, as was recently pointed out by Edwards[4], in possessing a propleural hair further differed from *Neocellia*. The larva of *A. rufipes* (another *Neocellia* which Edwards regards as being really a *Myzomyia* with well-developed ornamentation), however, is typical of Group 2, in spite of the possession of a propleural hair by the adult.

Group *Pseudomyzomyia*, Christophers. (Group 3 of Puri.)

The only South African Anopheline belonging to this group of Christophers is *A. gambiae*, Giles. The larva, however, resembles those of *Myzomyia*, except that the anterior ventral of the mesothorax is sometimes branched. In no specimen was the anterior dorsal of the prothorax merely split into two or three; it was always branched as in *Myzomyia.*

Group *Neomyzomyia*, Christophers. (Group 4 of Puri.)

Here belong *A. natalensis*, Hill & Haydon, and *A. ardensis*, Theo. The pleural hairs of these show some variation. Individual hairs may be simple, as in Puri's definition, but usually some member of the groups is split, but never feathered. The posterior dorsal hair of the prothorax, for example, is not simple in any of the specimens examined. Other pleural hairs which are commonly split are as follows:—Prothorax: anterior dorsal, posterior ventral; mesothorax: anterior dorsal, posterior dorsal; metathorax: anterior dorsal, posterior dorsal.

The Larvae of Anopheles natalensis, Hill & Haydon, and A. ardensis, Theo.

The larvae of these two species have always presented some difficulty. Recently a number of *A. ardensis* larvae were collected in a hill stream in the Drakensberg Mountains near Leydsdorp, in the North Eastern Transvaal. A study of these has revealed the fact that they are easily separable from those of *A. natalensis*, even under a low power, by virtue of the abdominal tergal plates (fig. 2).

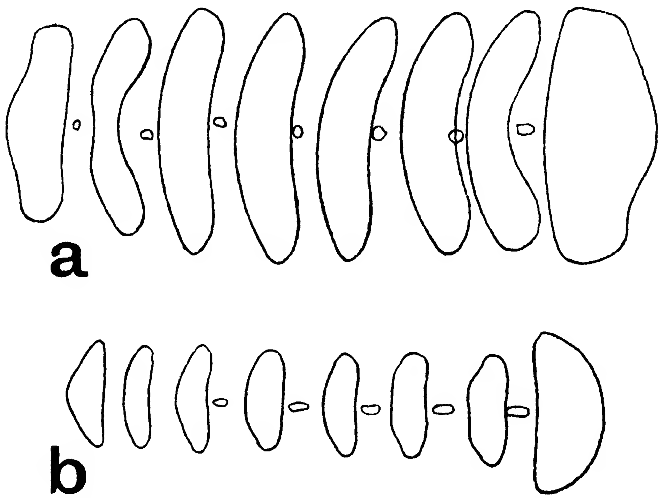

Fig. 2. Abdominal tergal plates of: (*a*) *Anopheles natalensis*; (*b*) *A. ardensis*.

The filaments of the abdominal palmate hairs are on the whole somewhat shorter than in *natalensis*, as has been pointed out by Bedford[1], but this is not an easily appreciable difference.

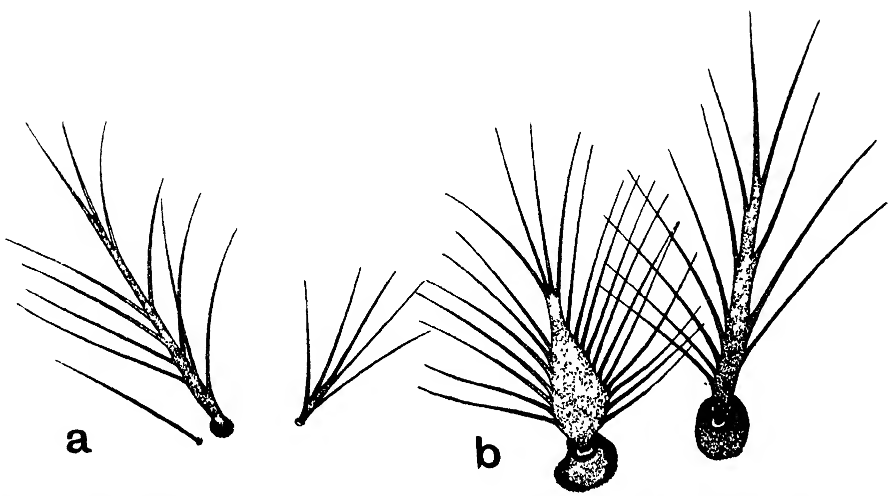

Fig. 3. Shoulder hairs, showing actual relative positions: (*a*) *Anopheles gambiae*, left pair; (*b*) *A. natalensis*, right pair.

An interesting variation shown by these larvae of *ardensis* and, as was subsequently discovered, by *natalensis* as well, is the branching of the hair on the shaft of the

antenna. In some it is double and in others even split into three. The hair, of course, is quite short and not to be compared with the large much-branched one of *mauritianus*.

A character by which the larvae of these two species and that of *nili*, which by its pleural hairs has been shown to be a *Neomyzomyia*, can be distinguished from other South African Anopheline larvae is the development of the shoulder hairs: the members of a pair are very widely separated, a feature also of the larva of *gambiae* (fig. 3, *a*), but furthermore the main stem of the inner hair of a pair is greatly flattened. The external hairs are also somewhat flattened (fig. 3, *b*).

An important Variation in the Larva of Anopheles squamosus, Theo.

The larva of this species is usually diagnosed by the dendriform external anterior clypeal hair. This is a very conspicuous object and is only approached in character by the larva of *mauritianus* among South African Anophelines. It is therefore of interest to note a variation shown by some larvae of *squamosus* collected at Richard's Bay, Zululand.

Hill & Haydon[7] noted that the external clypeal hair of one of their specimens was penniform and not dendriform. Evans[6] also remarks that the branching of this hair is variable and that it may be simpler than in the larva of *pharoensis*. In the present series of specimens, however, this hair is quite simple or with only one or two short lateral branches. Except for this the larvae appear to be inseparable from those of *squamosus*. Adults reared from larvae showing this variation were inseparable from adults reared from normal larvae.

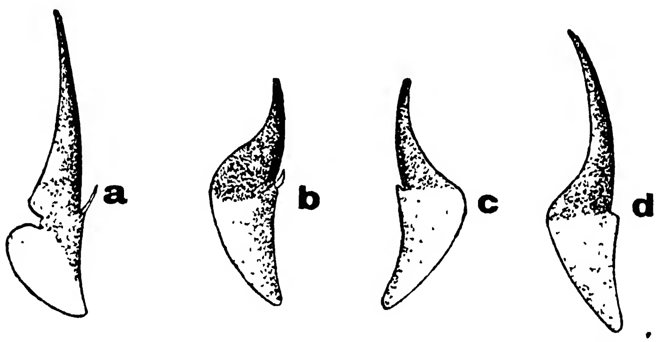

Fig. 4. Basal spine accompanying mesothoracic pleural hairs of: (*a*) *Anopheles squamosus*; (*b*) *A. cinereus*; (*c*) *A. gambiae*; (*d*) *A. argenteolobatus*.

Such larvae of *squamosus* are likely to be mistaken for those of *gambiae*. The larva of the last named species has, of course, no palmate hair on the thorax, but the absence or presence of this hair is often a difficult matter to decide on, especially in the field. A character by which the larva of *gambiae* can always be known is the relatively feeble development of the shoulder hairs, especially the internal ones (fig. 3, *a*). The only other South African Anopheline larva with such poorly developed shoulder hairs is that of *mauritianus*, which however cannot possibly be mistaken for that of *gambiae*.

From the larva of *argenteolobatus* these *squamosus* larvae appear to be inseparable, but we have not enough material at present to be certain on this point.

A feature which is easily seen in all larvae of *squamosus* is the well-developed basal spine accompanying the mesothoracic pleural hairs (fig. 4, *a*). Other species which have these spines developed to the same extent are, *A. gambiae*, *A. pharoensis*, *A. argenteolobatus* and, to a less degree, *A. cinereus* (fig. 4, *b–d*).

A scheme for separating these larvae is as follows :

1. Anterior pairs of pleural hairs short, thick, all feathered ... *cinereus*
   Anterior pairs of pleural hairs longer, thinner ; the anterior ventral hair of the mesothorax, at least, simple 2
2. Submedian thoracic hairs feebly developed (fig. 3, *a*) ... ... *gambiae*
   These hairs well developed 3
3. External clypeal hairs simple ... ...*argenteolobatus* and *squamosus* var.
   External clypeal hairs dendriform 4
4. Filaments of leaflets of abdominal palmate hairs long ... ... *squamosus*
   Filaments of these hairs short or nearly absent ... ... *pharoensis*

The Larva of Anopheles theileri, Edw., Typical Form.

Edwards[4] has recently divided the old species *Anopheles theileri*, Edw., into several varieties. Blacklock & Evans[2] described the larva of *A. theileri* from Sierra

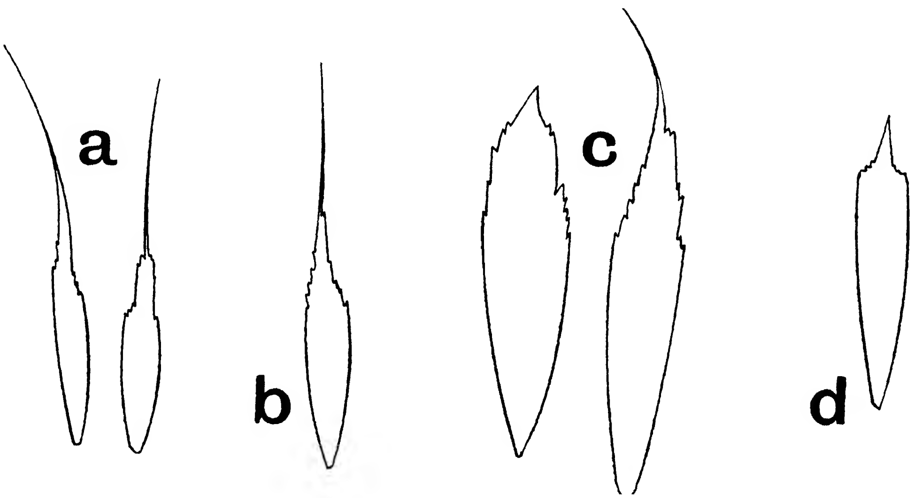

Fig. 5. *Anopheles theileri*, leaflets from palmate hairs of larva : *a*, from the thorax, *b*, from the 1st abdominal segment, and *c*, from the 5th abdominal segment, of the larva of the typical form ; *d*, from the 5th abdominal segment of the West Coast variety (after Evans).

Leone, and this, I take it, is Edwards' *A. theileri* var. *brohieri*. It is therefore of great interest to find support for Edwards' division of the adults in a difference between the larva of the typical form and that of at least one variety.

This easily perceptible difference between the larvae of varieties is well known in the case of *A. marshalli*, even though the adults are often very difficult to separate. As long ago as 1925, Evans[5] wrote that " it seems probable that larval characters will be found to be a very good means of separating the closely allied species of the *marshalli* group." It would now appear that this is also true of the type and at least one variety of *theileri*.

The chief differences between the larva of the type and the West Coast variety are as follows :—

A. theileri, type	*A. theileri* var.
Leaflets of the palmate hairs without shoulders, serrated, the apical ends being drawn out to a delicate filament. Some of the leaflets of the palmate hairs of the abdominal segments have the ends rather more bluntly pointed, but even then there is no shoulder (fig. 5, *b*, *c*).	Leaflets with a definite shoulder and no filaments to the leaflets of abdominal palmate hairs on segments 3 to 7 (fig. 5, *d*).
Palmate hairs of the thorax and first abdominal segment well developed (fig. 5, *a*, *b*).	Palmate hair of the thorax rudimentary, that of the first abdominal segment small.
There is very little difference in the lengths of the long and short teeth of the lateral comb (fig. 6).	Long teeth of the lateral comb much longer than the short teeth.

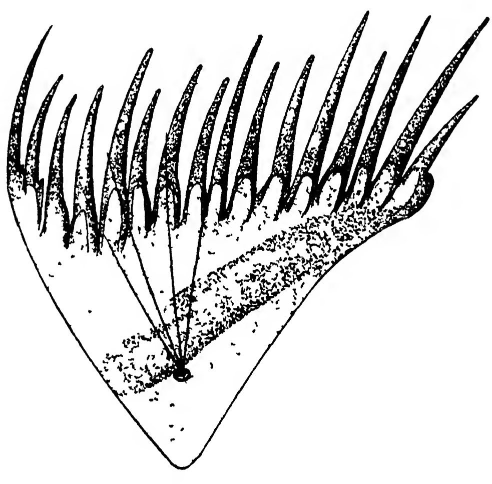

Fig 6 *Anopheles theileri*, typical form, lateral comb of the larva

The following characters are not mentioned by Blacklock & Evans in their description and are given here for further comparison between the two species.

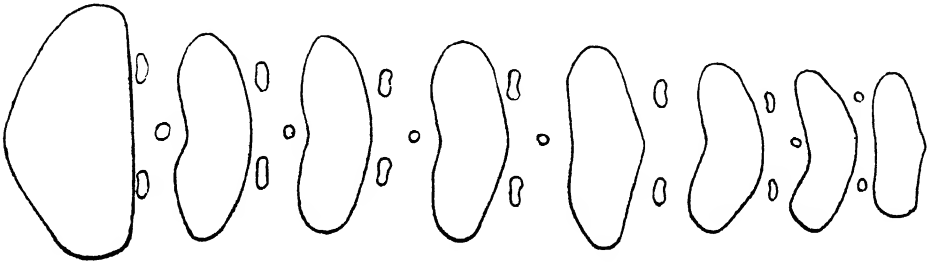

Fig. 7. *Anopheles theileri*, type, plaques of abdominal segments one to eight of the larva.

Shoulder hairs well developed and mounted on a common chitinous base. Hair at the apex of the antenna bifid or single, not very much longer than the terminal spines. Abdominal plaques large and, as in the larva of *A. longipalpis*, each large plaque is accompanied by three smaller ones (fig. 7). Lateral hair of the anal saddle single and simple.

Described from eight pelts. The pupa of the typical form was described and figured by Ingram & De Meillon[8].

Locality. Warmbaths, Transvaal, iii.1928.

Habitat. Larvae were found hugging the sides of a rapidly flowing stream in company with those of *A. funestus* and *A. longipalpis*.

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A NEW THRIPID (THYSANOPTERA) FROM SOUTH AUSTRALIA.

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I am indebted to the Imperial Institute of Entomology and to Mr F. Laing, of the British Museum, for submitting to me for classification a small collection of Thysanoptera from the Waite Agricultural Research Institute, Glen Osmond, South Australia. All measurements in this paper are in μ

Thripidae.

Hemianaphothrips (Anaphothrips) concinnus, sp. n.

Holotype ♀ (figs 1, 2) General body colour pale yellowish brown, with the pterothorax orange shaded with light brown The colour is due to a pale greyish brown cuticle covering the yellowish mass of the insect The dorsal surface of the

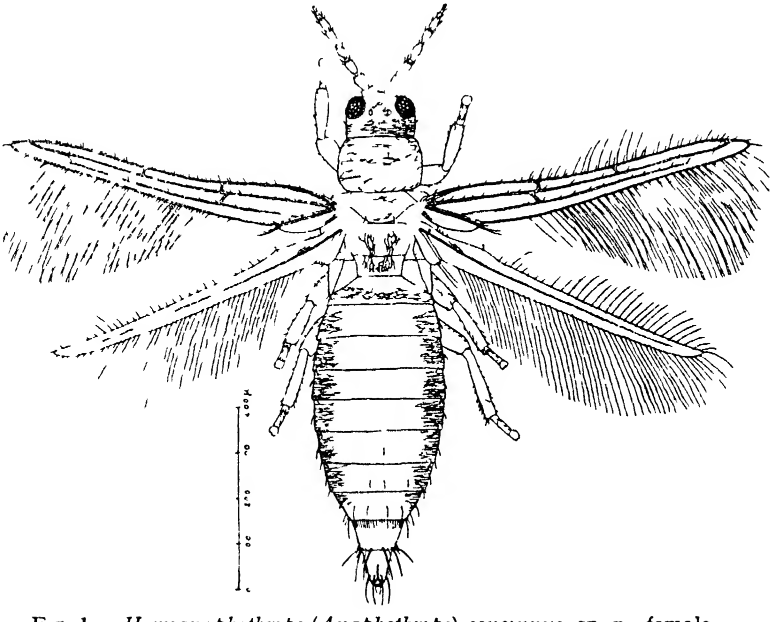

Fig 1 *Hemianaphothrips* (*Anaphothrips*) *concinnus*, sp n , female

abdomen is indistinctly maculated, since the grey brown colour becomes darker in the striated region between the second hair from the middle and the strong anterior lateral hair of each of terga III–VIII, and just posterior to these dark patches lie paler yellowish brown areas. Terga IX–X are the same grey brown colour as the other segments, but IX is paler in the middle and X at the base Antennal segment I palest in antenna, pale yellowish grey, II darkest, dark grey brown, III–IX little paler than II, uniform grey brown, except for the slightly paler pedicel and base of III and an indistinct paler area just above the pedicels of IV–V. Eyes almost black. Ocelli with bright reddish brown pigment. Mouth-cone and ends of tarsi tipped with dark brown. Maxillary and labial palpi pale yellowish grey. Legs coloured like body, but slightly paler, with femora and tibiae darkest on the mid dorsal surface. Fore wing concolorous pale yellowish grey, with veins clearly marked ; hind wing pale yellowish grey, with a dark longitudinal vein. Ovipositor coloured like body

Hairs coloured like body, except the stiff hairs of antennal segments II–IV, all hairs on fore and hind wings and the lateral, ventral and apical stiff hairs of the abdomen, which are darker yellowish brown. The thicker parts of the cuticle are usually marked by faint, confluent striae, which are darker on the sides of the abdomen.

Measurements : Length (width) : antennal segments I 23 (26), II 32 (26), III 46 (17), IV 42 (17), V 35 (16), VI 35 (16), VII 11 (10), VIII 9 (7), IX 14 (4) ; total length of antenna 240 ; head 108 (150) ; median ocellus 8 (11) ; lateral 11 (11) ; eye 60 (48) ; mouth-cone 120 (120 at base) ; maxillary palp segments I 17 (6), II 12 (4), III 15 (3) ; labial palp segments I 3 (5), II 14 (3) ; prothorax 118 (156–180) ; pterothorax 180 (240) ; fore wing 708 (57 at middle) ; hind wing 648 (39) ; abdomen 750 (270) ; ovipositor 160 (100 at base) ; total length of insect 1110. Length of hairs : ante-, inter- and post-ocellar hairs 14, on pronotum 9–12, on abdominal segments II 11–17, IV 13–23, VIII 23–40, IX 70, X 23, 66, 58 ; teeth in comb of VIII 14–20.

Morphology like that of *H. tersus*, but the head is only slightly retracted into the prothorax ; antenna (fig. 2) shorter, with smaller segments and shorter strong hairs ; pronotum similar, with no extra strong hairs at the angles and with about 40 small scattered hairs (*tersus* has about 40, not about 14 small hairs as stated in the original description) ; fore wing costa with 30–31 short, 19 longer, more slender hairs ; first vein 14 hairs arranged more or less in three groups of 5 hairs near the base, 4–5 hairs near the fork and 4–5 hairs scattered at various intervals along the rest of the vein ; second vein 13–14 hairs ; alula 6 and 2 hairs ; abdomen like that of *tersus*, but VIII bears a comb of 26 teeth, and the abdominal hairs are shorter and darker ; X is split dorsally and probably this is the case in *tersus*, though I could not distinguish the split in that species.

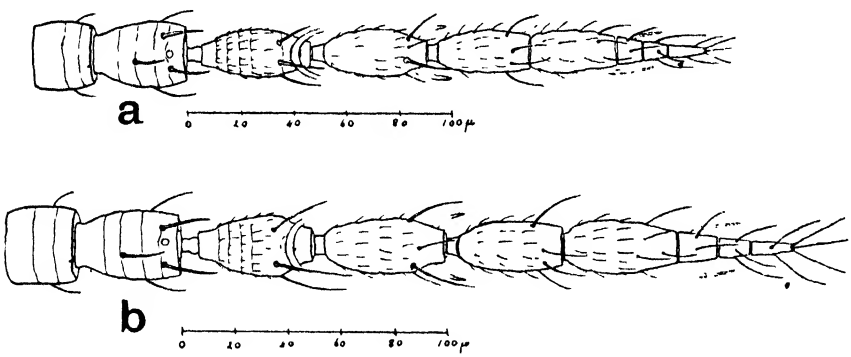

Fig. 2. Dorsal view of left antenna of female of : *a*, *Hemianaphothrips concinnus*, sp. n. ; *b*, *H. tersus*, Mor.

Allotype ♂ (fig. 3). Coloration like that of female, but paler, with yellowish brown vesiculae seminales conspicuous internally towards the end of the abdomen, and with all hairs and spines very pale yellowish grey except the hairs on the wings which are little darker yellowish brown.

Measurements : Antennal segments I 18 (20), II 32 (20), III 38 (16), IV 32 (15), V 32 (15), VI 32 (15), VII 8 (10), VIII 7 (7), IX 8 (4) ; total length of antenna 210 ; head 72 (114) ; median ocellus 6 (9), lateral 9 (11) ; eye 50 (35) ; mouth-cone 90 (96) ; maxillary palp segments I 13 (6), II 9 (4), III 15 (3) ; labial palp segments I 2 (4), II 9 (2) ; prothorax 85 (120–130) ; pterothorax 133 (170) ; fore wing 468 (42) ; hind wing 420 (30) ; abdomen 440 (165) ; penis 66 (34) ; regions occupied by curved bands of delicate chitin in urosterna III 37 (23), V 46 (30) ; VII band not visible, and width of each band is 4 ; total length of insect 670. Length of hairs : ante-, inter-

and post-ocellar 8, about 40 pronotal hairs each 8, on abdominal segments II 6–15, IV 8–18, VIII 9–26, IX (fig. 3) inner spine 12 (1·5 at base), outer spine 9 (1), hair B 52, C 44, D 35 ; X 18 ; teeth of comb on VIII 14.

Morphology like that of female. Fore wing costa 21 short, 12 longer more slender hairs ; first vein 9–10 arranged in three groups of 3 hairs near the base, 3 near the fork and 3–4 scattered at various intervals along the rest of the vein ; second vein with 5–7 hairs arranged in two groups of 2–3 hairs near fork and 3–4 scattered irregularly along the distal half of the vein ; alula with 5 and 2 hairs. Urosterna III–VI (and perhaps VII) bear each a transverse band of delicate chitin which curves back and then inwards. Abdominal chaetotaxy like that of female, except that VIII bears a comb of 22 teeth. Besides other hairs IX bears dorsally 2 pairs of slender spines.

Described from 1 ♀ holotype and 1♂ allotype found on *Lycium horridum*, Burnley, Victoria, S. Australia, 11.xii.29.

Thirty ♀♀, 2 ♂♂ and 7 nymphs II were found with the specimens chosen as types, and as all the insects seem to belong to the same species I call the other adults paratypes. The holotype, allotype, paratype 1♂ and paratypes many ♀♀ are deposited in the British Museum, and other paratypes have been returned to the Waite Institute.

Variation in ♀♀: The depth of coloration is probably correlated with age as occurs in many other Thripids. The coloration of the holotype is that of a female bearing many eggs of which one is nearly mature. In younger females distinguished by numerous immature eggs, the coloration is much paler so that the insect appears pale yellow with the prothorax darker yellow and the pterothorax orange and the grey brown colour of the cuticle only faintly marked. In older females, distinguished by few eggs, the coloration is much darker so that the insect appears almost concolorous dark yellowish brown. Seen against white china, in the holotype the head, prothorax and abdomen are about the same general yellowish brown, and this is about the same depth of colour as the orange pterothorax ; in young females the pale yellowish head, prothorax and abdomen are paler than the orange pterothorax ; in old females the yellowish brown head is paler than the prothorax which is paler than the orange brown pterothorax which is paler than the yellow brown abdomen. Measurements : Antennal segments III 43 (20), IV 37–43 (17), V 38 (18), VI 33–38 (14–17) ; fore wing 670–780 (57–64) ; costa with 26–36 short and 17–26 fringing hairs ; first vein with 10–18 hairs irregularly arranged ; second vein with 11–17 hairs ; hind wing 612–690 (36–42) with 24–31 anterior fringing hairs ; comb of VIII with 24–28 teeth ; abdominal hairs IX 70–80, X 23–26, 62–72, 50–60 ; total length of insect 960 contracted, 1200 partly distended. An abnormal antenna was borne by each of four females : in one ♀ V was sharply curved, in two others VI–VII and in another VIII–IX were incompletely separated.

Variation in ♂♂ : The 2 ♂♂ paratypes are very similar to the allotype. Fore wing 500 (44) ; costa with 24 short and 15 long fringing hairs ; first vein with 9–12 hairs ; second vein with 5–10 hairs ; hind wing 450 (30), with 14–18 anterior fringing hairs ; total length of insect 840 partly distended.

The 7 nymphs II are quite typical of Priesner's ANAPHOTHRIPINI, but I do not propose to describe them as they are not very well preserved.

In the Bull. Ent. Res., xxi, pp. 9–11 (1930), I described *Hemianaphothrips tersus* as the first species of its genus to be found in Australia. *H. concinnus* is very similar to *tersus*, yet ♀♀ are easily separated by their darker yellow colour with brown more marked ; by the structure (fig. 2) and colour of the antennae which are darker with apex of III the same colour brown as IV–IX, whilst in *tersus* III is much paler than IV–IX ; IV–V darker and more homogeneously coloured ; hairs on body and wings

shorter and more conspicuous because darker; veins of wings easily seen; fore and hind wings shorter and narrower; ovipositor smaller. The ♂♂ (fig. 3 and fig. 1 *loc. cit.* p. 10) are easily separated by the chaetotaxy of abdominal segment IX, as well as by other morphological characters. There is a distinction between nymphs II.

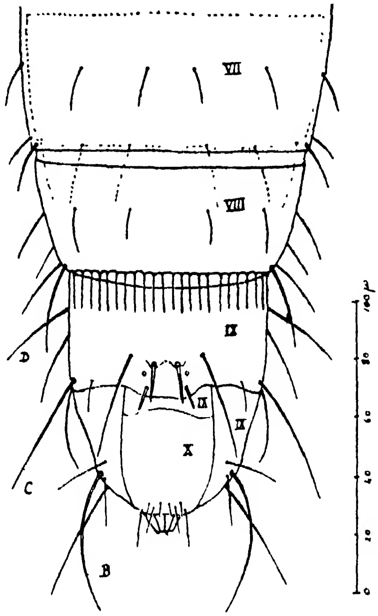

Fig. 3. *Hemianaphothrips concinnus*, sp. n., apex of abdomen of male. Sternum VII is shown in dots.

Limothrips cerealium, Haliday.

2 ♀♀, typical dark specimens, tomatos, Maffra, Victoria, 25.xii.29.

Limothrips angulicornis, Jablonowski.

7 ♀♀ with *L. cerealium.*

Thrips imaginis, Bagnall.

3 ♀♀, 1 ♂ carnations, 4.ii.30; 41 ♀♀, 15 ♂♂ rose, 11.xii.29; 1 ♀ *Lycium,horridum*, 11.xii.29, Burnley, Victoria; 1 ♂ tomatos, 25.xii.29, Maffra, Victoria.

Thrips tabaci, Lindeman.

5 ♀♀ carnations, 4.ii.30; 1 ♀ rose, 11.xii.29; 1 ♀ *Lycium horridum*, 11.xii.29, Burnley, Victoria.

PHLOEOTHRIPIDAE.

Haplothrips victoriensis, Bagnall.

1 ♀ carnations, 4.ii.30; 1 ♀, 1 ♂ rose, 11.xii.29, Burnley, Victoria.

THE CRITICAL POINT OF PARASITISM AND THE LAW OF MALTHUS.

By F. MUIR,

Hawaiian Sugar Planters' Experiment Station, Honolulu, T. H.

The law of population, as finally expounded by Malthus, conceives that increase depends upon the availability of food or upon the ease, difficulty, or ability of procuring it. The consideration of the action of parasites from this point of view, I believe, is of interest and importance, both from the economic and biological standpoints.

If we represent the action of an economically effective parasite species upon its host, either by Thompson's* formulae or by means of graphs†, it always leads, theoretically, to the extermination of the host. In nature this rarely, if ever, happens and it is therefore necessary to consider the weakness of our theoretical considerations.

A constant phenomenon that I have observed in the field, when the action of a parasite upon its host is studied over a considerable time and area, is as follows. When the host is very numerous the percentage of parasitism will rise very high, but when the host is scarce the percentage of parasitism becomes low. Observations carried out over twenty years in Hawaii, on *Perkinsiella saccharicida* (sugar-cane leaf-hopper), have demonstrated this contention for the species mentioned. Observations on other members of this genus, in the Malay Islands, have shown similar results. The same thing has been observed in a number of other cases, and I believe we can accept it as a general rule.

One of the weaknesses of our theoretical conceptions is that we have not taken the above facts into consideration. In such a formula as Thompson's, the rate of effective reproduction of the parasite population must be shown to decrease with the decrease of host, if we wish to approximate to actual conditions found in the field. If the host population be static, at the time of the introduction of the parasite, then its reduction will be gradual; the percentage of parasitism will increase gradually up to a certain point, and then both host and the percentage of parasitism will decrease rapidly. If the host population be still increasing, when the parasite is introduced, the percentage of parasitism will increase up to a certain point, while the host population shows little or no diminution; then both the host population and the percentage of parasitism will fall off very rapidly. The point at which the host ceases to decrease in the former case, and falls off rapidly in the latter, I would term the *critical point* of parasitism.

That these are not purely theoretical considerations is demonstrated by the work in the Hawaiian Islands. There the sugar-cane leaf-hopper (*Perkinsiella saccharicida*) was in a static condition when the egg parasites *Paranagrus optabilis* and *Ootetrastichus beatus* were introduced, and a gradual reduction of the host took place up to a certain point. This point varied in some situations on account of local conditions, but, except for local increases at times, the numbers of host and parasites remained static. Of these two egg parasites, *Ootetrastichus* is by far the larger and stronger, but *Paranagrus* has a higher rate of increase. Consequently, while the host was abundant, *Paranagrus* was overwhelmingly the more numerous, but upon the reduction of the host, the ratio between the two parasites was considerably reduced. These conditions remained fairly uniform for fifteen years, and then *Cyrtorhinus mundulus* was introduced. This egg-sucking Capsid bug is much larger and stronger than either of the egg parasites, is less affected by local conditions, a strong flyer and is positively tropic to sugar-cane. Its introduction caused the

* Ann. Appl. Biol., xvii, 1930, p. 322.
† Proc. Hawaiian Ent. Soc., iii (1), 1914, p 32.

reduction of the host (*Perkinsiella*) and brought down the local outbreaks to a negligible figure; the parasite population was also reduced and the numerical ratio of the two egg parasites still further diminished.

The sugar-cane borer beetle (*Rhabdocnemis obscura*) was also stationary when the Tachinid (*Ceromasia sphenophori*) was introduced. Subsequently a gradual reduction of the host took place up to the critical point, which varied in different localities, especially where conditions increased the difficulties of the parasite discovering its host.

In the case of the sugar-cane root beetle (*Anomala orientalis*) the host population was still on the increase when the Scoliid parasite (*Scolia manilae*) was introduced. The host showed little decrease for some time, although the parasite increased greatly—then suddenly the host numerically declined and has remained fairly constant in number ever since. Slight local increase due to conditions shielding the host from the parasite, such as heavy crops covering in the ground and preventing the access of the parasite, has occurred at times.

If we could plot curves correctly, showing the decrease of the host and the corresponding percentage of parasitism, it is highly probable that they would show a varying relationship which could be represented mathematically; the percentage of parasitism would fall more rapidly as the critical point was reached. The curves for different parasites would differ considerably.

I believe that all the above facts can be generalised under the law of Malthus, which states that the increase of a population (in this case the parasites) depends upon the availability of food, or upon the ease, difficulty, or ability of obtaining it. This ability, in any one parasite species, is fairly constant, and as it is taxed more and more as the host decreases, so the parasite becomes less and less effective. There comes a point (*the critical point of parasitism*) when the parasite can exist but can produce no further effect upon the host population.

As an economic factor this critical point is one of the most important characteristics of a parasite. The nearer it approaches to the extermination of its host the more effective it will be economically. Parasites with a high critical point (approaching near to host extermination) form the " key " parasites of a biological complex or association. This does not mean that the rest of the factors in the complex are of no economic importance, but that they only act as a drag upon the increase of the host, without ever subjugating it. This was well illustrated in the Hawaiian Islands, where there were some twenty enemies of *Perkinsiella* when this pest first appeared, yet they were unable to prevent its increase, although they must have acted as a drag. Upon the introduction of the two egg parasites the host was reduced, and upon the introduction of *Cyrtorhinus* it was still further reduced.

The case of overlapping death factors has been discussed by several workers, and H. S. Smith* has gone into the question of multiple parasitism, quoting the case of *Opius* and *Diachasma* in Hawaii. I fully agree with Smith's opinions so far as they go, for I have held all along that the case against *Diachasma* has never been proven. If we consider the case from the viewpoint discussed above, it is possible that some new light may be thrown upon it. The percentages of parasitism prevalent at different times have been used in this discussion, but no idea of the host population has been given, so that their relations to one another cannot be estimated. The drop in host population since the first introduction of the parasites has been enormous. Coffee is cultivated in a small area on one of the islands and guava grows wild over miles of the mountain side. Before the introduction of the fruit-fly parasites it was difficult to find either a coffee berry or a ripe guava free from fly larvae, most of them being attacked by a number of maggots; to-day coffee is little affected, and one can gather all the guavas one needs quite free from maggots. Some fruits, which

* Bull. Ent. Res., xx, 1929, pp. 141–149.

appear extra attractive to the fly, still are heavily affected, but even there the number of larvae in each fruit is not so great. But it makes little difference economically if a peach harbours two or twenty maggots.

There are other cases of overlapping of death factors in the work in Hawaii. In the sugar-cane field *Ootetrastichus* is "intrinsically superior" but "extrinsically inferior" to *Anagrus*, especially when the host population is high; when they meet in the larval stages the former species overcomes the latter. The habits of these two parasites were known to Perkins and Koebele when they introduced them into Hawaii, but from their field experience, they considered the two would be better than the one. Their judgment was justified by the results. At the time of introducing *Cyrtorhinus*, the writer placed on record that it sucked both parasitised and unparasitised eggs, but he maintained that its introduction would be economically sound. This judgment has been amply justified by results, as it is both "intrinsically" and "extrinsically" superior to the egg parasites.

It is perhaps on account of such cases as those enumerated that some workers have concluded that entomologists in Hawaii have imported all the parasites and predators found attacking the pest without very much regard to their possible or probable interaction. There could be no more erroneous conclusion. Such questions cannot be settled in a laboratory, but must be judged in the field, and the fact that the Hawaiian entomologists have made no great errors should demonstrate that they have not acted without due consideration. Nowhere has mass introduction, either of species or specimens, been so strongly discountenanced.

What controls the critical point of parasitism is a question too large to discuss at the present time. Fundamentally it is due to the psychology, physiology and morphology of an insect, but it is modified by physical and biological environments. It is the differences and interactions of these factors which cause the differences between the critical points of parasitism of different insects.

SOME NEW INJURIOUS PHYTOPHAGA FROM SOUTH AFRICA.

By G. E. Bryant,

Entomologist, Imperial Institute of Entomology.

Family Eumolpidae.

Rhembastus pomorum, sp. n. (fig. 1).

Oblong-ovate, metallic dark blue; clypeus, antennae and legs fulvous; prothorax finely and remotely punctured; elytra finely punctate-striate, with the interstices glabrous. *Length,* 4 mm.

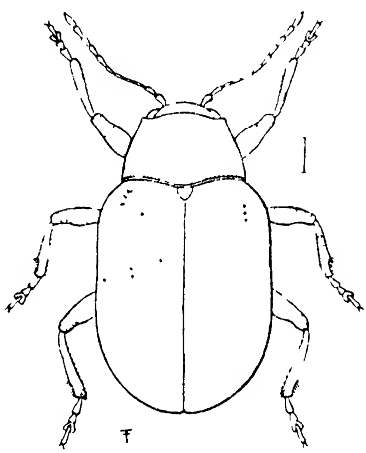

Fig. 1. *Rhembastus pomorum,* sp n

Head metallic dark blue, finely and remotely punctured, a longitudinal impression extending from the clypeus to the middle of the head, and at the base a short median longitudinal carina, the clypeus and labrum fulvous. Antennae long and slender, fulvous, with the four apical joints slightly fuscous, the first joint short and rounded, the second to the seventh slender and about equal to each other, the four terminal joints slightly thickened. Prothorax deep metallic blue, finely and remotely punctured, broadest behind the middle, with the sides converging in front, a distinct line of punctures along the basal margin, but broken in the middle. Scutellum, subtriangular, dark metallic blue, impunctate. Elytra dark metallic blue, slightly broader at the base than the prothorax, with the sides behind the middle slightly tapering to the apex, very finely punctate-striate, with the interstices glabrous. Legs fulvous, with the femora slightly fuscous, all the femora strongly punctured, more so on the apical third. Underside blue-black, not metallic, with very fine grey pubescence on the ventral segments.

Transvaal: Potchefstroom, 4.xi.1924 (*R. Owen Wahl*).

Reported as injuring young apples and foliage.

Allied to *R. variabilis*, Har., but the puncturation very much finer, with a more glabrous appearance, and less convex.

This is evidently a very variable species in colour, as the three specimens before me are, respectively, entirely metallic blue, metallic blue with the prothorax red, and entirely fulvous.

Scelodonta vitis, sp. n. (fig. 2).

Reddish cupreous, elytra and underside finely pubescent, terminal joints of the antennae with a blue tinge ; head strongly punctured, prothorax transversely strigose, elytra somewhat rugosely punctured at the base, the posterior two-thirds punctate-striate and longitudinally costate ; sides of the breast with dense white pubescence. *Length*, 4 mm.

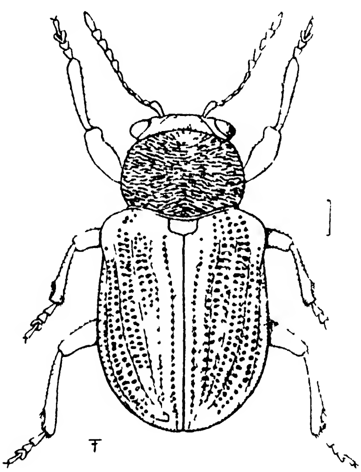

Fig. 2. *Scelodonta vitis*, sp n.

Head with strong scattered punctures, sparingly clothed with short white hairs, which are thicker and longer near the eyes, the vertex with a short longitudinal groove, the lateral sulci very deep ; clypeus with strong scattered punctures. Antennae extending just beyond the base of the elytra, with the five basal joints cupreous, the rest with a blue tinge. Prothorax transverse, the sides rounded, the surface transversely wrinkled, with a few punctures forming a V-shape at the middle of the anterior margin. Scutellum transverse, pentagonal, with a group of punctures in the centre. Elytra broader at the base than the prothorax, the shoulders prominent, with a strong impression below the shoulder ; the basal portion rugosely punctured, and the apical two-thirds rugosely punctate-striate, slightly costate, more so towards the apex, with rows of white hairs between the striae. Legs with all the femora strongly punctured, clothed with scattered white pubescence. Underside with the ventral segments of the abdomen punctured and clothed with white pubescence, the sides of the breast with a stripe of dense white pubescence.

Natal : Ixopo, 24.ix.1927 (*L. B. Ripley*).

Feeding on grape-vine foliage.

Allied to *S. natalensis*, Baly, and *S. pectoralis*, Jac., but distinguished by the longitudinal groove on the head being shorter and shallower, and the punctures on the head more scattered and widely spaced ; the puncturation of *S. pectoralis* is altogether more rugose on the elytra. It is closer to *S. natalensis* in the puncturation of the elytra, but the colour will at once distinguish it.

Family Halticidae.

Notomela fulvicollis, sp. n. (fig. 3).

Oblong, reddish fulvous, the apical joints of the antennae black; prothorax with scattered punctures; elytra dark metallic blue, finely punctate-striate, longitudinally costate near the lateral margin. *Length*, 4 mm.

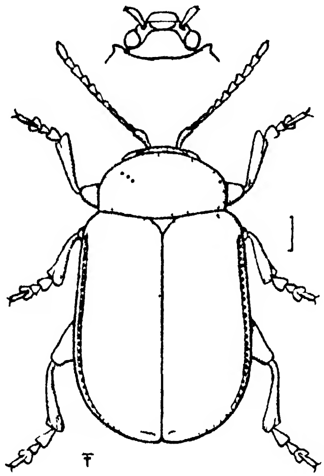

Fig. 3. *Notomela fulvicollis*, sp n

Head fulvous, with a few scattered punctures; clypeus impunctate, separated from the face by a transverse groove. Antennae extending a short way beyond the base of the elytra, the five basal joints fulvous, and the six terminal joints black, the basal joint thickened, and about equal in length to the second and third together, the third nearly twice as long as the second, the others shorter and gradually transversely thickened. Prothorax fulvous, very transverse, the sides parallel near the base, converging in front, the anterior angles forming a small tooth; the surface with rather large scattered punctures. Scutellum triangular, fulvous, and impunctate. Elytra oblong, dark metallic blue, slightly wider at the base than the prothorax, slightly rounded at the apex; finely punctate-striate, the punctures forming irregular double rows, more so on the apical half, the lateral margin strongly costate. Underside and legs fulvous, abdomen with scattered punctures, and the apical half of all the femora strongly punctured.

Natal: Durban, 27.x.1922. Transvaal: Pretoria, xi.1929 (*H. K. Munro*).

Reported as feeding on leaves of *Xanthoxylon capense*. Closely allied to *N. cyanipennis*, Jac., but differs in the puncturation, that on the prothorax very much more scattered and irregular, and the elytral striae not nearly so closely geminate.

Longitarsus crotalariae, sp. n. (fig. 4).

Winged; flavous, the suture and the upper half of the posterior femora fuscous; head impunctate, prothorax finely punctured, elytra finely and densely punctured. *Length*, 2 mm.

Head impunctate, with a well-developed frontal carina; the labrum fuscous. Antennae long and slender, extending beyond the middle of the elytra, the front joint long and about equal in length to the second and third together, the fourth

about equal to the first, and slightly longer than the fifth, the seven terminal joints about equal, the four terminal joints tinged with fuscous, and the terminal joint notched near the apex. Prothorax broader than long, the sides slightly emarginate, and the anterior angles oblique; the surface finely and closely punctured. Scutellum subtriangular, impunctate. Elytra slightly widened behind the middle and rounded at the apex; the surface more strongly punctured than the prothorax, a strong regular line of punctures along the side margins, and the sutural line fuscous. Legs flavous, with the exception of the posterior femora, the upper half being fuscous. Underside glabrous, the ventral segments of the abdomen clothed with very short pubescence.

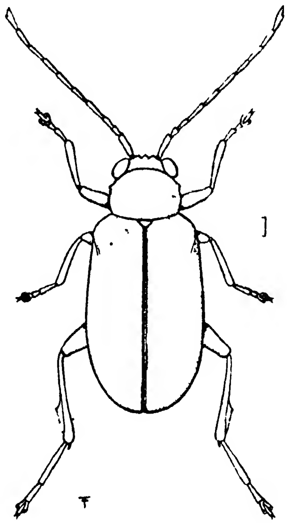

Fig. 4. *Longitarsus crotalariae*, sp. n.

TRANSVAAL: Tomango, xi.1927 (*C. J. Joubert*).

Reported as feeding on leaves of Sunn Hemp (*Crotalaria juncea*).

Allied to *L. africanus*, Jac., but easily recognised by its dark suture; also its surface is not granulate, and it is winged.

Family GALERUCIDAE.

Monolepta munroi, sp. n. (fig. 5).

Dark violaceous blue, antennae black with the exception of the three basal joints flavous; prothorax very finely punctured, elytra finely and closely punctured, but more strongly than the prothorax. *Length*, 4 mm.

Elongate-ovate, widened posteriorly; the head metallic greenish blue, very finely punctured, the frontal elevations distinct, impunctate; the labrum black. Antennae extending to the middle of the elytra, the three basal joints fulvous, the third joint long and about equal to the first two together, the fourth joint longer than the third or fifth, the remaining joints about equal to each other, the eight terminal joints black. Prothorax transverse, metallic blue, widest at the base, the sides strongly deflexed and margined, contracted in front, the anterior angles thickened;

the surface very finely punctured. Scutellum metallic blue, triangular and impunctate, elytra metallic violaceous blue, much longer than broad, convex and widened posteriorly, finely and closely punctured, but the puncturation stronger than that on the prothorax. Legs black, clothed with short grey pubescence, long and slender. Underside metallic blue-black, the ventral segments about equal to each other, very finely punctured, and clothed with short grey pubescence.

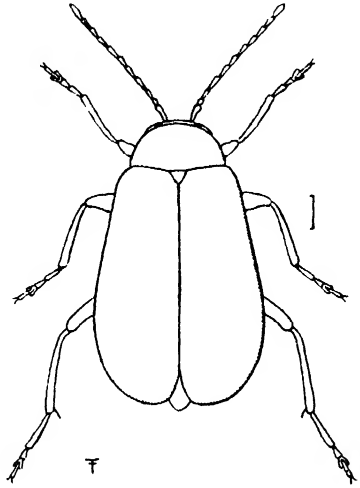

Fig. 5. *Monolepta munroi*, sp. n.

TRANSVAAL: Warmbaths, Roodekuil, 6.xii.1929 (*H. K. Munro*).

Feeding on *Acacia*.

Closely allied to *M. kirschi*, Jac., but distinguished by the prothorax being finely punctured and the basal joints of the antennae fulvous.

FIVE NEW SPECIES OF SPATHIUS (HYM. BRACON.).

By D. S. Wilkinson,

Entomologist, Imperial Institute of Entomology.

Since a fairly extensive collection of the Braconid genus *Spathius*, largely comprised of bred series of new species, had lately been received for identification by the Imperial Institute of Entomology, and since there were various species in the British Museum awaiting description, it was considered opportune that I should attempt some sort of revision of this comparatively little worked but nevertheless quite interesting group : it is hoped to publish my results shortly. In the meanwhile, however, the following descriptions are presented since most of these names are required at an early date for inclusion in a paper on the biology of these parasites.

Spathius cavillator, sp. n.

♀. Red testaceous to dark red, with portions of all femora and the median fourth to half of all tibiae often decidedly blackish ; all trochanters and trochantines together with the extreme base of all femora, all tibiae basally, the palpi, basal third of the stigma, and metacarp basally, more or less colourless, as are sometimes the anterior coxae ; wings infumated, with a darker area beneath the apical two-thirds of the stigma, this latter, together with the basal vein and certain portions of the medial vein, being dark red-brown to blackish, the remaining veins red-brown.

♀. *Head* : face rugose, the rugae very irregular but on the whole running transversely ; facial depressions not well marked, their distance apart rather greater than their distance from the eyes ; the grooves delimitating the clypeus oblique, the clypeus thus long ; the clypeus not so coarsely sculptured as the remainder of the face ; eyes with length only about 1·2 times their breadth, this latter 1·64 times the malar space ; distance of ocelli from eyes at least three times the distance between the posterior pair ; frons and vertex with strong rugae, those on the frons more or less regular and concentric with the antennal insertions, those in the neighbourhood of the ocelli irregular, those on the vertex regular and transverse ; the occiput with strong, transverse striation, which is weaker or absent behind the eyes and altogether absent on the cheeks ; the cheeks highly shining and smooth, thus contrasting with the face ; flagellum with about 40 joints, the scape rather shorter than the 1st flagellar joint and rather longer than the 2nd. *Thorax* : mesonotum strongly rugose and setiferous, and to some extent coriaceous, the rugae on the whole transverse, with the crenulate notauli very well marked and posteriorly converging on a large median sunken area, which in addition to the transverse rugae has two longitudinal carinae ; the lower, horizontal, mesopleural sulcus in the anterior two-thirds strong and very strongly crenulate, definitely continued to the posterior margin of the mesopleurae but here weaker and more weakly crenulate, and the anterior, perpendicular sulcus very well marked and with strong, transverse (horizontal) carination which does not extend on to the rest of the mesopleurae ; mesopleurae otherwise shining and smooth save for some deep, concentric striation immediately posterior to the anterior perpendicular sulcus ; propodeon with the dorsal areation as figured (fig. 1), but with the degree of transverse rugosity variable, shining and smooth between the rugae or possibly very indistinctly and very weakly coriaceous. *Wings* : fore-wing with the 1st abscissa of the medial vein not decurved nor closely approaching the 1st abscissa of the anal vein. *Abdomen* : 1st tergite stout, parallel-sided, medianly somewhat swollen dorsally, and with apex broadened, shorter than the combined length of the remaining tergites ; 2nd and succeeding tergites entirely smooth (save for a few setae) except that the 2nd possibly has some very weak, short striation at extreme base ; the 2nd and 3rd tergites together shorter than the combined length of the succeeding tergites ; ovipositor sheaths equal to or shorter than the abdomen.

Length, 5·0–5·5 mm.

INDIA : Phanduwala, Dehra Dun, United Provinces, 3 ♀♀ (one the *type*), 24.vi.1929, 26.vi.1929 ; Kanchad, W. Thana, Bombay, 1 ♀, 4.xi.1929 (*C. F. C. Beeson*) ; Manon Range, N. Thana, Bombay, 1 ♀, 28.vi.1930 (*C. F. C. Beeson*).

Type deposited in the British Museum.

Host. The specimens from Phanduwala are recorded as " ex *Terminalia belerica*," that from Kanchad as " ex *Thespesia populnea*," and that from Manon Range as " ex unknown climber."

Spathius elaboratus, sp. n.

♀♂. Red ; the tarsi (except the apical joint) often largely whitish ; the tegulae, and the 2nd and succeeding segments of the abdomen, strongly darkened to black, the 2nd tergite often suffused with red ; palpi and ovipositor sheaths dark ; wings infumated but not strongly so, hyaline at apex, in a narrow band beneath the basal fourth of the stigma (which also is pale to hyaline), and in a large area on, and around, the middle of the basal abscissa of the medial vein.

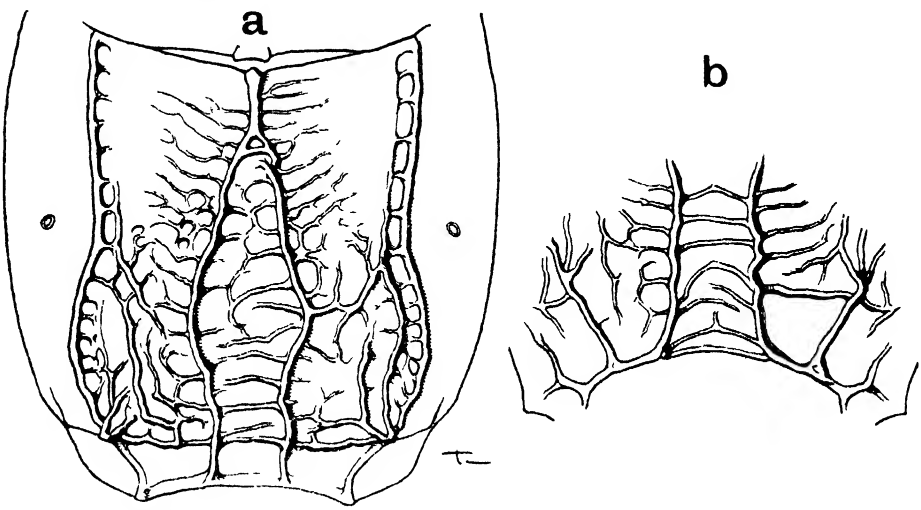

Fig. 1. *Spathius cavillator*, sp. n. : *a*, dorsal areation of propodeon ; *b*, the extreme posterior areation of propodeon viewed posteriorly.

♀♂. *Head* : face with transverse, more or less rugose carination, and medianly in the upper third with a narrow perpendicular area that is entirely smooth ; the clypeus not so coarsely sculptured ; facial depressions distinct but not well marked, their distance apart equal to their distance from the eyes ; the grooves delimitating the clypeus oblique, the clypeus thus long ; eyes with length about 1·2 times their breadth, this latter 1·64 times the malar space ; distance of ocelli from eyes three to 2·4 times the distance between the posterior pair ; frons, vertex (and in ocellar triangle), and median occiput with well-marked, close, transverse, often quite strong striation, this often weak however, particularly on the frons ; cheeks smooth and shining, thus contrasting with the face ; flagellum with 31–33 joints in the ♀, and apparently 26–29 joints in the ♂, the scape equal to the 1st flagellar joint and longer than the 2nd. *Thorax* : mesonotum coriaceous and shining, with the crenulate notauli very well marked and posteriorly converging on a large median sunken area, which has two longitudinal, and numerous transverse, widely spaced and cleanly marked carinae ; the lower, horizontal, mesopleural sulcus present only in the anterior two-thirds, shallow, rather broad, and with weak crenulation, and the anterior,

perpendicular, sulcus present as a broad, striate or carinate area whose sculpture extends on to the upper half of the mesopleurae; mesopleurae otherwise shining, smooth or slightly coriaceous; propodeon of ♀ with the dorsal areation as figured (fig. 2), in the area on each side of the median basal carina coriaceous. *Wings*: fore-wing with the 1st abscissa of the medial vein not strongly decurved nor closely approaching the 1st abscissa of the anal vein. *Abdomen*: 1st tergite stout with the spiracles prominent, shorter than the combined length of the remaining tergites; 2nd tergite evenly throughout minutely and weakly reticulate; 3rd tergite apparently coriaceous in basal half or very minutely reticulate, minutely coriaceous in apical half, smooth at extreme apex; 4th and succeeding tergites minutely coriaceous basally, exceedingly minutely coriaceous to smooth apically; 2nd and 3rd tergites together equal to or rather shorter than the combined length of the succeeding tergites; ovipositor sheaths shorter than abdomen.

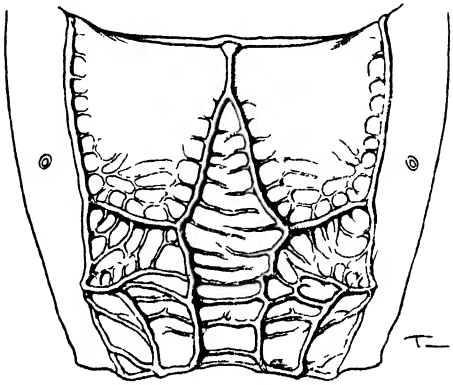

Fig 2. *Spathius elaboratus*, sp. n.: dorsal areation of propodeon

Length, 3·0–4·5 mm.

INDIA: Jhajra, Dehra Dun, United Provinces, 16 ♀♀, 4 ♂♂, 21–26.v.1924, 30.v.1924 (*type*), 15.vi.1924 (*N. C. Chatterjee*), 2 ♀♀, 15 & 19.vi.1925 (*B. M. Bhatia*), 4 ♀♀, 3 ♂♂, 12–25.xi.1924 (*C. F. C. Beeson*); Lachiwala Range, Dehra Dun, 3 ♀♀, 11 & 12.xii.1920 (*C. F. C. Beeson*).

Type deposited in the British Museum.

Host. The material from Jhajra dated May and June of 1924 and 1925 is labelled " ex *Ficus rumphii*," while that dated November is labelled " ex *Odina wodier* "; the material from the Lachiwala Range is labelled " ex *Vitis latifolia*."

The areation of the male propodeon differs somewhat from that of the female, the median longitudinal basal carina being decidedly longer in the former.

Spathius festinans, sp. n.

♀♂. Black, with the head and all femora and tibiae dark red-testaceous to red-black; anterior coxae with their trochanters (but not their trochantines), apex of hind coxae, the hind trochanters (but not the hind trochantines), majority of all tarsi, scape, flagellum (except apically), ovipositor sheaths more or less (except apically), and palpi, stramineous to pale red-testaceous; the ovipositor red; fore-wings with large areas infumated, the extreme base stramineous to white, as is the basal fourth of the stigma; hind-wings more or less hyaline; wings with all veins, and stigma in apical three-fourths, dark red-brown.

♀♂. *Head*: face throughout (except for a very narrow smooth area medianly in the upper half, and for the clypeus whose rugae are definitely weaker) with strong, closely placed, transverse rugae; facial depressions strongly marked, the area immediately surrounding them depressed (and often smooth) and thus emphasising them,

their distance apart just greater than their distance from the eyes; the grooves delimitating the clypeus well marked, oblique, the clypeus thus long; eyes with length about 1·3 times their breadth, this latter about twice the malar space; distance of ocelli from eyes twice the distance between the posterior pair; the whole of the frons, vertex, and median occiput (even in the ocellar triangle) with strong, close, transverse carination; on the occiput laterally this carination bends forward strongly so that here and behind the eyes it is not transverse but longitudinal; as the cheeks are approached this carination becomes weaker; cheeks shining and smooth, thus contrasting with the face; flagellum broken in every specimen, the scape decidedly shorter than the 1st flagellar joint and equal to the 2nd. *Thorax*: mesonotum coriaceous and shining, with the strongly crenulate notauli very strongly marked and posteriorly converging on a large median deeply sunken area, which has two longitudinal, and numerous short transverse, widely spaced and well marked carinae; the lower, horizontal, mesopleural sulcus definitely present in the anterior two-thirds and with strong indications of being continued to the posterior margin, shallow and rather broad and with weak crenulation, and the anterior, perpendicular sulcus present as a very broad, setiferous, horizontally carinate area, whose carination extends over the upper half of the mesopleurae; mesopleurae otherwise shining, smooth or slightly coriaceous; propodeon with the dorsal areation as figured (fig. 3), shining, in the area on each side of the median basal carina coriaceous between the rugae.

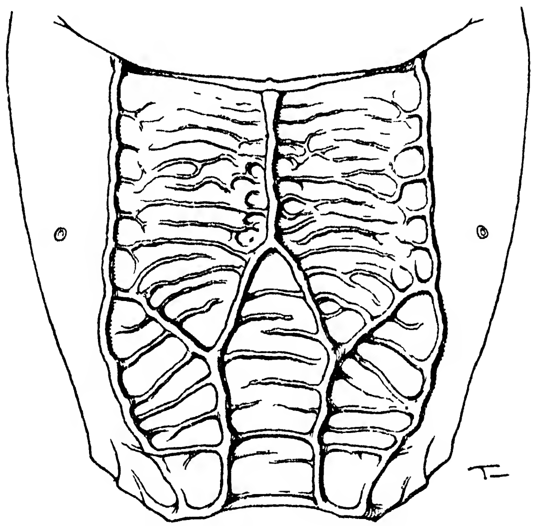

Fig. 3. *Spathius festinans*, sp n. dorsal areation of propodeon.

Wings: fore-wing with the 1st abscissa of the medial vein not strongly decurved nor closely approaching the 1st abscissa of the anal vein. *Abdomen*: 1st tergite fairly slender with the apex decidedly broadened and the spiracles prominent, in length about equal to the combined length of the remaining tergites; 2nd tergite evenly throughout minutely and weakly reticulate; 3rd tergite minutely and very weakly reticulate on about basal half to three-fifths, the apical portion throughout with very fine, close but distinct, transverse, concentric and/or parallel striation, but possibly smooth on extreme apex; succeeding tergites with exceedingly fine rugose or reticulate aciculation basally, exceedingly fine transverse striation apically, and smooth at extreme apex; the sculpture of the male throughout rather stronger than as above; 2nd and 3rd tergites together in ♀ equal to or rather shorter than, in ♂ equal to or rather longer than, the combined length of the succeeding tergites; ovipositor sheaths longer than the abdomen.

Length : ♀, 5·5–6·5 mm. ; ♂, 5 mm.

INDIA : Koina R., Singhbhum, Bihar & Orissa, 5 ♀♀, 1 ♂, 24.iv.1921, 27.iv.1921 (*type*), 28.iv.1921, 19.v.1921 (*C. F. C. Beeson*).

Type deposited in the British Museum.

Host. This material is labelled " ex *Mangifera indica*."

Spathius generosus, sp. n.

♀♂. Dark red to almost black, with the following parts almost invariably lighter or even red testaceous: antennae, palpi, tegulae, thorax ventrally, and all legs including coxae; tibiae basally, and the basal two-fifths of the hind tibiae, stramineous; ovipositor red; wings to some extent infumated, the wing-veins and stigma red-brown, with the latter pale in basal third.

♀♂. *Head* : face with weak, transverse rugosity, in the upper half with a narrow, median, perpendicular area that is smooth; facial depressions distinct but not well marked, their distance apart rather greater than their distance from the eyes; the grooves delimitating the clypeus oblique, the clypeus thus long; eyes with length 1·3 times their breadth, this latter 1·7 times the malar space; distance of ocelli from eyes about three times the distance between the posterior pair; frons with transverse striation; vertex, occiput, and cheeks smooth and shining, thus contrasting with the face; flagellum with apparently about 33 joints, the scape about equal to the 1st flagellar joint and longer than the 2nd. *Thorax* : mesonotum coriaceous, the weakly crenulate notauli well marked and posteriorly converging on a large median sunken area, which has two longitudinal and some rugose carinae; the lower, horizontal, mesopleural sulcus present only in the anterior two-thirds, with extremely

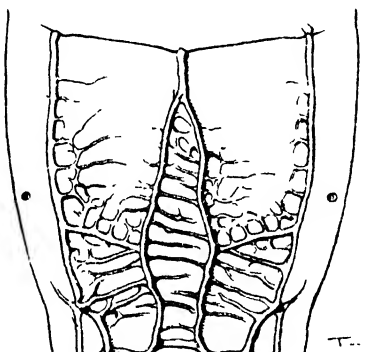

Fig. 4. *Spathius generosus*, sp n. : dorsal areation of propodeon

weak crenulation, and the anterior, perpendicular sulcus not well delimitated and with horizontal, rather widely spaced, weak carination which extends on to the upper half of the mesopleurae; mesopleurae otherwise shining and smooth; propodeon with the dorsal areation as figured (fig. 4), in the area on each side of the median basal carina and of the median area with numerous fine rugae giving almost a coriaceous effect, and apparently really coriaceous at base. *Wings* : fore-wing with the 1st abscissa of the medial vein not decurved nor closely approaching the 1st abscissa of the anal vein. *Abdomen* : 1st tergite fairly stout with the spiracles prominent, shorter than the combined length of the remaining tergites; 2nd tergite of ♀ evenly throughout minutely rugose, with some minute reticulation; 3rd tergite of ♀ in basal half with minute, separated punctures or aciculations, in apical half smooth, thus contrasting with the 2nd tergite and rendering its apical margin distinct; succeeding tergites with increasingly minute and sparse punctation basally; the

sculpture of the tergites in the ♂ coriaceous, with the apical limitation of the 2nd tergite consequently not well marked; 2nd and 3rd tergites together equal to or rather shorter than the combined length of the succeeding tergites; ovipositor sheaths longer than the abdomen.

Length, 3·5–4·5 mm.

INDIA: Deoban Range, Chakrata, 9 ♀♀, 26 & 29.viii.1912, 1 ♂, 2.ix.1912.

Type deposited in the British Museum.

Host. This series is labelled as having been bred out from a pole of *Cedrus deodara*.

Spathius piperis, sp. n.

♀♂. Red; the 2nd tergite usually darkened, sometimes even nearly black; ovipositor sheaths darkened; flagellum at and towards the apical half, wing-veins, and stigma, red-brown, the latter basally, together with the base of the metacarp, stramineous; wings definitely infumated, the infumation as strong in both wings and even throughout save for some slight indication of a narrow hyaline band in the fore-wing beneath the basal fourth of the stigma.

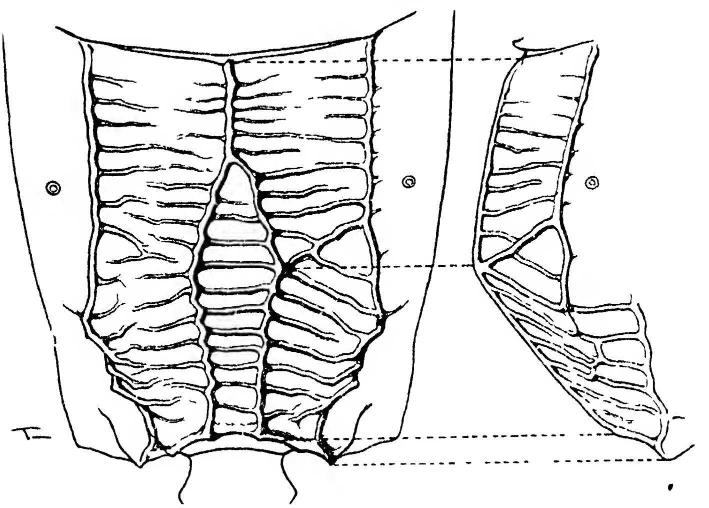

Fig. 5. *Spathius piperis*, sp n.: dorsal areation of propodeon—on right, lateral view.

♀♂. *Head*: face transversely rugose; facial depressions distinct, their distance apart equal to their distance from the eyes; the grooves delimitating the clypeus oblique, the clypeus thus long; eyes with length about 1·25 times their breadth, this latter 1·9 times the malar space; distance of ocelli from eyes quite three times distance between posterior pair; frons distinctly coriaceous with some transverse carination; vertex and median occiput with strong, transverse carination and between which apparently coriaceous; hind orbits distinctly coriaceous; cheeks with certain rugosity, sometimes distinctly rugose, also coriaceous to some extent, but not smooth and shining, and not contrasting with the face; flagellum with 27–36 joints in the ♀, and 25–33 in the ♂, the scape equal to the 1st flagellar joint and rather longer than the 2nd. *Thorax*: mesonotum coriaceous and dull, the crenulate notauli well marked and posteriorly converging on a large median slightly sunken area, which has two longitudinal and some weak transverse carinae; mesopleurae coriaceous and with irregular, widely spaced, well-marked carinae; the anterior, perpendicular, mesopleural sulcus indicated almost only by the slightly greater irregularity of the general carination, the lower, horizontal sulcus however definitely present in the anterior

two-thirds and crenulate; these crenulations often form an almost complete carina along the lower margin of the sulcus, as they terminate here and their ends are slightly turned, whereas above the sulcus they merge into the general carination of the mesopleurae; propodeon with the dorsal areation as figured (fig. 5), with much strong transverse carination between which it is coriaceous and dull. *Wings*: fore-wing with the 1st abscissa of the medial vein not strongly decurved nor closely approaching the 1st abscissa of the anal vein. *Abdomen*: 1st tergite fairly slender, shorter than the combined length of the remaining tergites, with the middle of the basal two-thirds strongly and evenly (not abruptly) swollen dorsally and laterally, this swelling stronger dorsally than laterally; 2nd and succeeding tergites with well-marked, longitudinal, more or less parallel striation or carination, the extreme apex of the 3rd and of the succeeding tergites smooth; 2nd and 3rd tergites together equal to or rather shorter than the combined length of the succeeding tergites; ovipositor sheaths shorter than the abdomen.

Length: ♀, 3·0–4·5 mm.; ♂, 2·5–4·0 mm.

DUTCH EAST INDIES: Pangkalpinang, Banka, 17 ♀♀, 10 ♂♂, 1930 (*J. v. d. Vecht*, through *R. W. Paine*).

Type deposited in the British Museum.

Host. Recorded as a larval parasite of the weevil, *Lophobaris piperis*, Mshl., on *Piper nigrum*.

DESCRIPTIONS AND RECORDS OF PARASITIC HYMENOPTERA FROM BRITISH GUIANA AND THE WEST INDIES.

By J. G. MYERS, Sc.D., F.E.S.,

Imperial Institute of Entomology.

The following notes are based almost entirely upon actual rearing records, the hosts in most cases being insects of economic importance. The greatest attention has been paid to parasites of the small moth-borers of sugar-cane (*Diatraea* spp.). The systematic work has been done entirely at the British Museum and would have been impossible without the facilities in literature and collections there, and the great help of Mr. D. S. Wilkinson and Dr. C. Ferrière, of the Imperial Institute of Entomology. Types of new species are in the British Museum.

Family BETHYLIDAE.

Perisierola bogotensis, Kieffer, 1908.

This insect was described from five examples which emerged from cocoons found in a stem-gall of *Eupatorium*, caused by a Lepidopterous larva in Colombia.

Three specimens reared from one larva of *Diatraea saccharalis*, Fabr., in Berbice, British Guiana, agree exactly with the fairly adequate description and key given by Kieffer (Das Tierreich, 41 Lief., p. 541, 1914).

Family ICHNEUMONIDAE.

Stenarella sp.

One male reared from the full-fed caterpillar of the mahogany-tip borer (*Hypsipyla grandella*) at Mabaruma, North-West District, British Guiana, agrees with the description of *S. brevicaudis*, Szép. (Ann. Mus. nat. Hungar., xiv, 1916, p. 318) save in minor colour characters. The description, which is reasonably detailed, is based on a single female from Peru.

Polycyrtus lituratus, Brullé, 1846.

This insect, corresponding closely with Brullé's description, based on Cuban specimens, was reared in numbers from the cocoons of the moth, *Margaronia hyalinata*, a common pest of Cucurbitaceous plants in Cuba. It is indistinguishable also from the type of *Polycyrtus blanditus*, Cameron (Biol. Centr. Amer., Hymen. i, p. 235, pl. ix, fig. 21, 1885) which is in the British Museum. It was taken in Haiti also.

Spilocryptus diatraeae, sp. n. (fig. 1).

Head transverse ; eyes large ; vertex passing by a moderately sharp curve into the occiput ; vertex and temples wide ; cheeks short ; clypeus transverse, but slightly produced medially ; antennae rather short, the first to fourth segments of flagellum thinner than the rest, but individually thickened apically ; remaining antennal segments more nearly cylindrical. Thorax considerably longer than deep ; parapsidal furrows deeply but narrowly impressed, strongly crenulate ; mesonotum swollen, rounded, suddenly depressed towards the unarmed scutellum ; propodeon with two curved transverse crenulate furrows near the base, meeting in the middle line like a well-spread italic *w* ; propodeon posteriorly truncate, with two stout outwardly directed tooth-like tubercles ; spiracles broadly elliptical. Radial cell of fore-wing rather short, not reaching wing-tip ; end of radius proceeding almost straight from the areola but bending up to the costa just before the latter ; areola pentagonal, the costal side slightly the longest, otherwise fairly regular, sides almost parallel ; not

petiolate; nervus recurrens interstitial; nervus parallelus arising below the middle of the brachial cell (*i.e.*, nearer the hind margin of the wing); nervulus widely antefurcal; nervellus (hind wing) antefurcal. Legs not long; hind coxae considerably longer than wide. Abdomen elliptical (♀); first segment strongly bent; post-petiole slightly longer than wide; spiracle circular.

Head smooth, shining; vertex, temples, cheeks and face finely punctured but still shining; mesonotum closely, evenly and deeply punctured; scutellum less distinctly so; propleura and mesopleura similarly strongly punctured, but with a tendency to form transverse lines; propodeon with very dense, even, rugose, deep punctures with round pits; petiole and post-petiole almost smooth, very shining; rest of abdomen extremely finely but shallowly punctured, giving a distinctly matt appearance.

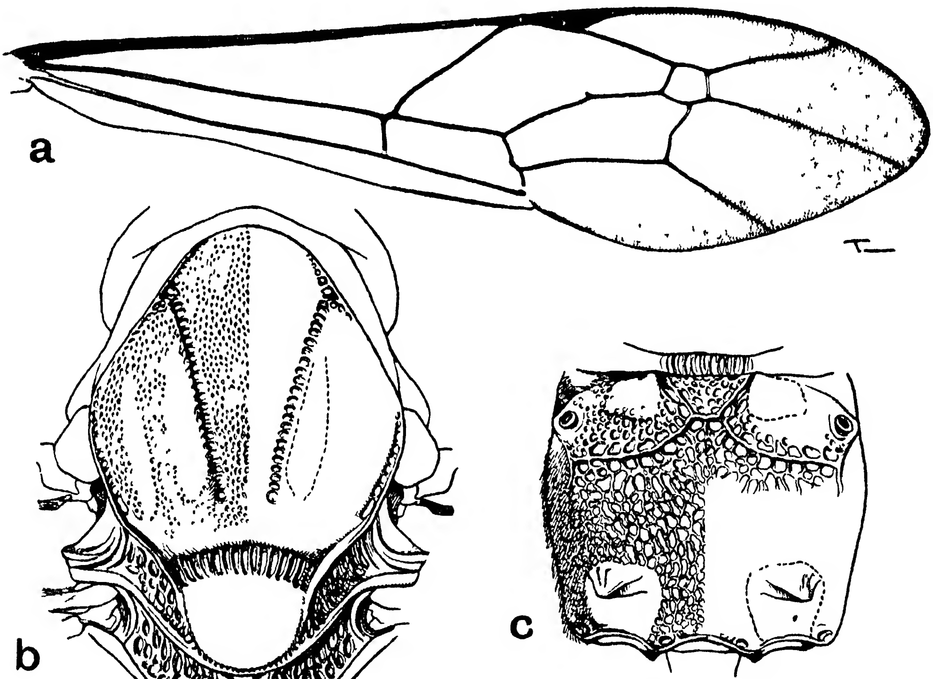

Fig. 1. *Spilocryptus diatraeae*, sp. n.: *a*, fore-wing; *b*, mesonotum and scutellum; *c*, propodeon.

Head and thorax and most of antennae black; a ring round the eyes (complete save just near the mandibles), middle of clypeus, middle band of antennae (about 3½ segments beginning at middle of fifth flagellar segment), prothoracic collar, outer borders of parapsidal furrows (especially distally), tegulae, most of scutellum, a tiny spot in middle of post-scutellum, a small spot on each side of base of propodeon, two larger spots distally (surrounding and including the tubercles), a small spot on mesopleura, all greenish white; sterna unrelieved black. Abdomen, legs and ovipositor clear chestnut-red, the ovipositor a little darker, the legs a little paler. Wings clear, the veins and stigma black. Some short white pubescence on face, pleura, and propodeon.

Length, ♀, 13 mm.; ovipositor 4·5 mm. additional; ♂, 10 mm.

BRITISH GUIANA: Berbice.

Described from three females and two males reared from cocoons in burrows of *Diatraea* spp. Possibly a hyperparasite attacking *Ipobracon grenadensis*, Ashm.

This is probably the *Mesostenoideus* sp. recorded by Box as a parasite of *Diatraea* in Berbice. It is the only *Spilocryptus* recorded from the New World tropics, and is, in some respects, intermediate between the genera *Spilocryptus* and *Hoplocryptus*. On the advice of Dr. Ferrière I place it in the former.

Acroricnus cubensis, Cresson.

Cryptus cubensis, Cresson, Proc. Ent. Soc. Philad., iv, p. 21, 1865.

Cresson records this striking species, which undoubtedly belongs to the genus *Acroricnus*, as " parasitic upon the larva of *Pelopaeus lunatus*, Fabr." The latter name is a synonym of *Sceliphron cementarius*, Drury.

One specimen of this, the only recorded tropical American species of *Acroricnus*, was captured inside the Harvard Laboratory, Soledad, Cuba, where it might easily have emerged from the mud nests of *Sceliphron*.

I am indebted to Mr. O. W. Richards for a reference to Champlain (Psyche, xxix, p. 99, 1922), who reared *Acroricnus junceus*, Cress., in Pennsylvania from the nest of a solitary wasp on *Juniperus* and also from that of *Odynerus tigris*. Mr. Richards states that these host-records are more in keeping with the habits of the European species.

Neotheronia bicincta, Cress.

Theronia bicincta, Cress., Proc. Ent. Soc. Philad., iv, p. 38, 1865.

Two males were reared from a cocoon of the moth, *Margaronia hyalinata*, at Soledad, Cuba.

Pimpla marginella, Brullé, 1846.

This handsome species was reared in some numbers from the cocoons of *Margaronia hyalinata* at Soledad, Cuba.

It is surprising that Schmiedeknecht (Gen. Ins., 62 fasc., 1907, p. 67), on the basis of Brullé's description, places this in *Ephialtes*, in spite of the fact that on page 66 of the same work he expressly states in the generic diagnosis that the ovipositor in *Ephialtes* is at least as long as and usually longer than the body; and that a sharp distinction between *Pimpla* and *Ephialtes* cannot be drawn, but all those species with elongate, more or less parallel-sided body, and an ovipositor at least as long as the body may be placed in *Ephialtes*. Brullé describes the body as $2\frac{1}{2}$ times as long as the ovipositor. My specimens, moreover, show the species to be a true *Pimpla*.

Xiphosoma nigrovittata, Cresson.

One specimen, San Blas, Cuba, feeling with its ovipositor in the opening of an abandoned Lepidopterous leaf-roll on a Rubiaceous shrub.

Xiphosoma annulata, Cresson.

Specimens determined by Mr. Wilkinson were found in some numbers parasitising a Phycitid larva, probably *Fundella cistipennis*, Dyar, feeding on the flowers and young pods of the cover-crop plant, *Canavalia ensiformis*, in Trinidad. Captured specimens were among the Cuban collections.

Family Braconidae.

Genus **Ipobracon**, sens. str.

Members of this abundant and very difficult genus are among the most important Hymenopterous parasites of the small cane moth-borers (*Diatraea* spp.) and the cacao-beetle (*Steirastoma depressum*) in Trinidad and British Guiana. In most cases

it has been possible to make comparison with the actual type specimens of the species concerned. Dr. Gahan has kindly compared some of our material with types in Washington.

Key to Ipobracon *spp. parasitising* Diatraea *in British Guiana and Trinidad.*

1. Stigma brilliant yellow 2
   Stigma black, wings heavily infuscate 5
2. Middle field of second segment quite smooth, tergites not punctured ... 3
   Middle field striate, with a median keel, tergites strongly punctured ... 4
3. Bright red with black head, legs red ; ovipositor longer than abdomen ... *grenadensis*
   Only abdomen red, thorax black or blackish, legs black ; ovipositor as long as abdomen ... ... *puberuloides*
4. Middle field of second segment broad, especially posteriorly, nearly as broad as long ; ovipositor shorter than abdomen ... ... *dolens*
   Middle field narrow, much longer than broad ; (only ♂ known) ... *saccharalis*
5. Hind tibiae expanded, furnished with stiff black hairs ... ... *pennipes*
   Hind legs normal ... ... *aquaticus*

Ipobracon grenadensis, Ashmead, 1900 (fig. 2, *a*).

This is by far the commonest species attacking *Diatraea* in Trinidad, British Guiana, and in Venezuela (specimens reared by Mr. Box, examined in the British Museum). In my very long bred series there are some specimens, which are usually darker than the average, showing signs of a small depression on each side of the disc of the middle field of the second segment. Others, just as dark, have no trace of this. The variation in size is also exceedingly great.

Ipobracon puberuloides, sp. n. (fig. 2, *b*).

♂. Face and front densely clothed with pale hairs ; vertex flat, with distinct minute even punctures, ocellar area abruptly raised ; head moderately narrowed behind the eyes. Antennae about 64-jointed, the scape finely punctured, shining, narrowed at base, the flagellar segments fluted ; third segment considerably longer than fourth. Thorax and propodeon very finely and evenly punctured, the nota clothed with dark, and the sides and propodeon more thickly with pale hairs. Mesonotum narrowed and elevated anteriorly, the parapsidal furrows strongly marked. First tergite as broad at the apex as long, the lateral carinae well developed, the median area very smooth and shining, the grooves between it and the lateral carinae very broad and transversely rugose. Second tergite with a smooth lanceolate median area from the base, narrowing rather quickly and reaching to two-thirds of the length of the tergite ; the anterior angles of the tergite depressed and marked off by a deeply-impressed crenulate furrow ; rest of tergite smooth and impunctate. Second suture and a suturiform sinuate transverse deeply-impressed line on third, fourth, and fifth tergites very minutely crenulate. Rest of these and of the other tergites smooth, shining, impunctate. Nervulus interstitial, recurrent vein practically interstitial.

Head, thorax, legs, antennae, apical tergite, and half of ante-apical, black ; eyes (black centrally) and mesosterna dark brown ; abdomen bright red. Wings infuscate, hyaline ; veins black. Stigma bright yellow with apical third and extreme base black.

Length, 10 mm.

♀. Ovipositor as long as abdomen.

British Guiana.

This is a parasite of various species of *Diatraea* in British Guiana, especially Berbice. It agrees with Szépligeti's description of *I. puberulus* (Term. Füzet., xxiv, p. 390, 1901, Brazil, Tonantins) save that the latter has the apical half of the fifth segment black, and a red line along the middle of the metanotum.

Ipobracon dolens, Cameron, 1911 (fig. 2, *c*).

In British Guiana and Trinidad this is second in abundance only to *I. grenadensis*, as a parasite of *Diatraea* spp. My reared specimens agree with the type in the British Museum, save that they all have the propodeon evenly and distinctly, though minutely punctured. In the type (a unique ♂ from Demerara) the propodeon is shining, and the punctures, though present, are rarer.

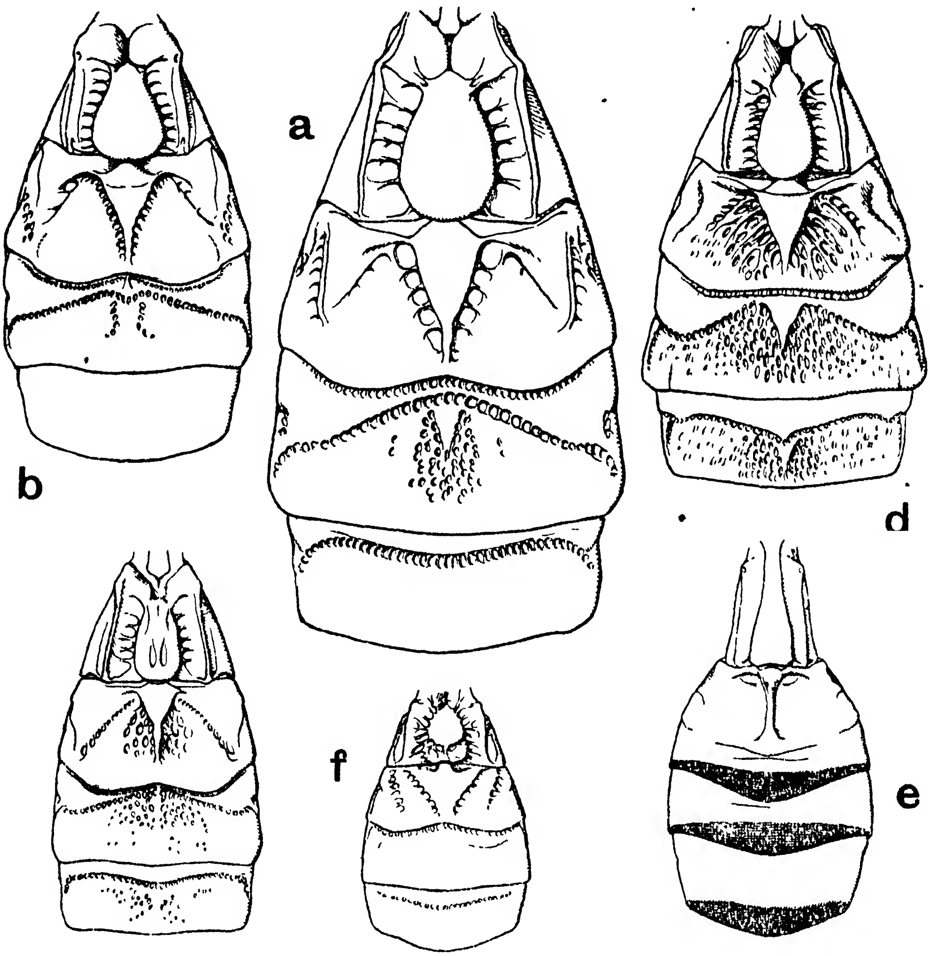

Fig. 2. Tergites 1–4 of: (*a*) *Ipobracon grenadensis*, Ashm.; (*b*) *I. puberuloides*, sp. n.; (*c*) *I. dolens*, Cam.; (*d*) *I. saccharalis*, Turn.; (*e*) *I. pennipes*, sp. n.; (*f*) *I. aquaticus*, sp. n.

Ipobracon saccharalis, Turner, 1918 (fig. 2, *d*).

This species, which is only with difficulty distinguished from the last and may eventually prove only an extreme variation of it, is still known only from the unique male type in the British Museum, reared from *Diatraea* larvae in sugar-cane. The different shape of the middle field of the second tergite seems a constant character in my long series of *dolens*, but several, which are undoubtedly *dolens*, show marked

signs of the smooth triangle at the base of the third tergite, a character which Turner considered diagnostic of *saccharalis*. He had only one specimen of *dolens*, however, to compare.

Ipobracon pennipes, sp. n. (fig. 2, *e*).

♀. Face and front coriaceous, clothed with long, rather sparse golden hairs; vertex flat and smooth, very faintly and sparsely punctate, the ocellar area swollen; head not strongly narrowed behind eyes, with slightly excavated posterior margin. Antennae about 50-jointed, about as long as the body without the ovipositor; scape coarsely punctured; flagellar segments strongly longitudinally ribbed; third segment only very slightly longer than fourth. Thorax practically impunctate, propodeon coarsely and evenly punctate; nota with only a few weak hairs laterally, mesopleura and propodeon clothed fairly thickly with long pale hairs. Mesonotum very swollen medially, but the parapsidal furrows not strongly marked. First tergite considerably longer than broad, the lateral carinae well developed, the median area quite smooth, the lateral grooves narrow and smooth. Second tergite with a rounded knob-like smooth median area at the very base, continued as a narrow longitudinal carina to the middle of the tergite; rest of tergite quite smooth, somewhat depressed on each side of median keel. Succeeding tergites smooth, with simple sutures; sides of abdomen with a few stiff black hairs. Ovipositor about as long as abdomen, with a dense covering of stout stiff black hairs. Nervulus just post-furcal; recurrent vein interstitial. Legs thickly clothed with stiff black hairs, especially the tibiae of the hind pair, which are moreover compressed and strongly dilated.

Colour shining chestnut-brown; the head, antennae, posterior half of third to sixth tergites and whole of last, and ovipositor, black. Legs and prosternum strongly infuscated, but appearing blacker on account of thick covering of black hair. Wings strongly infuscate, veins and stigma black.

Length, without ovipositor, 7 mm.

British Guiana: Berbice.

Described from one female and one of unknown sex (abdomen missing) reared from *Diatraea*.

This is an isolated species, easily distinguished by the extraordinarily flattened hind legs, and their bristly covering. *I. luctuosus*, Szépl. (*Iphiaulax*) (Ann. Mus. nat. Hungar., iv, p. 575, 1906), from Bolivia, seems the nearest of the described species, with similar proportions and coloration and bristly hind legs, but the second suture and forks of the first and second tergites are said to be crenulate.

Ipobracon aquaticus, sp. n. (fig. 2, *f*).

♀. Face and front coriaceous, with only a few long pale lateral hairs; vertex strongly convex, smooth, and shining, practically impunctate; scarcely narrowed behind the eyes; ocellar area swollen. Antennae about 42-jointed; scape sparsely punctate; flagellar segments fluted. Thorax practically impunctate, very smooth; propodeon coriaceous, mesopleura very sparsely and propodeon thickly clothed with weak pale hairs. Mesonotum swollen anteriorly, the parapsidal furrows not deep. First tergite rather wider than long, the lateral carinae well developed, the median area much depressed basally and elevated apically, strongly rugose, the grooves between it and the lateral carinae strongly transversely crenulate. Second tergite with a smooth triangular median area from the base almost to the apex, the groove separating this from the rest of the tergite being strongly crenulate; on each side of the median area the tergite is evenly coriaceous, save laterally where it is rugose. Between the coriaceous and the rugose portions anteriorly there is a strong line of demarcation, the rugose part being suddenly depressed. Second

suture strongly crenulate. Third and fourth tergites shining coriaceous, each with a short abrupt ridge in the anterior angle. Apical tergites shining, coriaceous, with a few hairs laterally. Ovipositor a little more than half the length of the abdomen. Nervulus interstitial; recurrent vein interstitial. Stigma greatly swollen.

Colour uniform reddish yellow, the apical tergites slightly infuscated; antennae, eyes, ocellar area, posterior part of mesosternum, tips of tarsi and claws, apex of hind tibia, ovipositor, stigma and wing-veins, black or blackish; wings strongly infuscate.

Length, without ovipositor, 4·7 mm.

♂. Somewhat paler. Antennae about 46-jointed.

British Guiana: Berbice.

Described from one female and two males reared from larvae of *Diatraea saccharalis*, boring in the aquatic grass, *Paspalum repens*.

This species agrees with Széplegeti's description of *I. braconiformis* (*Iphiaulax*) (Ann. Mus. nat. Hungar., ii, p. 179, 1904), from Peru, but the particulars given are too meagre to establish identity. It is a very small, Bracon-like species.

Ipobracon peronatus, Cameron.

Taken commonly among cacao trees in Trinidad and almost certainly parasitic on the cacao beetle (*Steirastoma depressum*). The specimens were determined by Mr. Wilkinson.

Ipobracon steirastomae, Viereck.

This species was reared from the larvae of the cacao beetle (*Steirastoma depressum*) in Trinidad. Specimens were compared with the type at Washington, by Dr. Gahan.

Ipobracon depressi, Viereck.

The same remarks apply to this as to the preceding species.

Apanteles diatraeae, Muesebeck.

This species, determined by Mr. Wilkinson, was reared from *Diatraea lineolata* in Trinidad, and found also on *Diatraea saccharalis* in Cuba.

Apanteles thurberiae, Muesebeck.

This is an efficient parasite of the pink bollworm, *Platyedra gossypiella*, in Trinidad. My specimens were determined by Mr. Wilkinson.

Genus **Microdus.**

There is a confusing difference between modern American and European usage of this name and *Bassus*. I have consulted Mr. Wilkinson and he agrees with the Swedish Ichneumonologist, Dr. Roman, that *Bassus* must still be considered an Ichneumonid genus, leaving *Microdus* for those Braconid forms which Viereck and other American workers group under *Bassus*.

Key to the Species of Microdus *parasitising* Diatraea *spp. in British Guiana and the West Indies.*

1. Stigma bright yellow, surrounded by a bright yellow area 2
   Stigma black, rest of wing infuscate ... ... *parvifasciatus*
2. First tergite distinctly rugosely striate at sides of median keel ... *stigmaterus*
   First segment smooth at sides of median keel ... ... *sacchari*

Microdus stigmaterus, Cresson, 1865 (fig. 3, *b*).

This is the most widespread larval parasite of *Diatraea* in tropical America. It has been introduced artificially into Barbados, Antigua, and Porto Rico, by Mr. Box, in the first two apparently unsuccessfully. It occurs naturally, if Cushman's synonymy be correct, on the mainland from Argentina to British Guiana, and throughout the islands from Trinidad northwards, so far as my observations go, wherever conditions are sufficiently moist. I have found it in Trinidad, St. Lucia, Montserrat, St. Kitts, Cuba, Haiti, and Jamaica. It almost certainly occurs in all the Greater Antilles.

Wherever it is found with the other species, it is the commonest of those attacking *Diatraea*. My reared specimens from British Guiana and Trinidad agree exactly with the type of Turner's *M. diatraeae*, and with the description (save in size) of *M. stigmaterus*, Cress., of which, according to Cushman (Ann. Ent. Soc. Amer., xxii, p. 633, 1929), the former is a synonym.

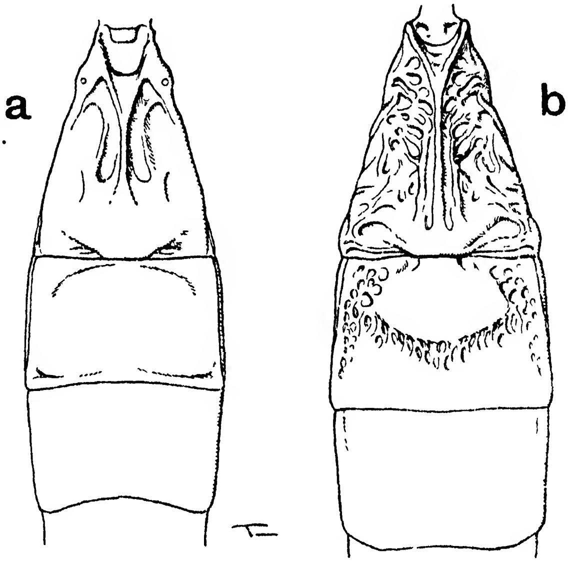

Fig. 3. Tergites 1–3 of : (*a*) *Microdus sacchari*, sp. n. ; (*b*) *M. stigmaterus*, Cress.

Microdus sacchari, sp. n. (fig. 3, *a*).

♀. Vertex shining, sparsely and indistinctly punctured; face shining, finely and closely punctured, much broader than long; frons depressed on each side of middle. Thorax strongly narrowed anteriorly, shining; parapsidal furrows distinct, but shallower than in *M. stigmaterus*; median lobe of mesonotum very smooth, with a longitudinal carina only faintly indicated, the lateral lobes very indistinctly and exceedingly sparsely punctured. Mesopleura, sides of propodeon and coxae finely and closely punctured. Propodeon shining, with acutely-angled lateral edges, two indistinct and irregular longitudinal carinae near middle, much stronger distally, and a few large scattered reticulations. First tergite nearly twice as long as its apical breadth, twice as broad at apex as at base, quite smooth and shining, with a distinct longitudinal carina (forked basally) from base to middle. Second tergite about two-thirds the length of the first, perfectly smooth and shining, with an oblique depression (rather than a groove) on either side from base to lateral margin, and a broad transverse depression near middle of segment. Sutures smooth.

Remaining segments perfectly smooth and shining. Spur of hind tibia slightly more than one-third the length of the hind metatarsus; claws simple. Second cubital cell triangular, not petiolate; radius reaching the costa a little nearer to apex of wing than to apex of stigma.

Bright red; head, antennae, and ovipositor black; wings strongly infuscate; stigma and a small area behind it bright yellow.

Length, 11 mm., ovipositor 15 mm.

BRITISH GUIANA: Berbice. TRINIDAD.

Described from three females reared from *Diatraea* larvae, in British Guiana and Trinidad.

This is closely related to the preceding species, but is easily distinguished by the wholly red thorax, the smooth first tergite and median lobe of mesonotum.

Microdus parvifasciatus, Cameron.

This dark-coloured species was described from Demerara. The unique male type is in the British Museum. Mr. Turner has placed it with the female type of *M.* (*Cremnops*) *maculipes*, Cameron, which is, however, badly damaged.

My only specimen, which was reared from *Diatraea*, came from Trinidad. None of my extensive British Guiana rearings yielded it.

Aphaereta apicalis, Ashm., 1895.

This remains the only recorded neotropical species in the genus. A series reared from the puparium of an undetermined Sarcophagid fly parasitising the larva of the arrowroot skipper, *Calpodes ethlius*, in Cuba, agrees with Ashmead's description and type (♀, in British Museum) save in size, which is 1·5 instead of 2 millimetres.

Superfamily CHALCIDOIDEA.

All the material listed in this group has been determined, through the Director of the Imperial Institute of Entomology, by Dr. C. Ferrière, to whom I am very deeply indebted.

Family CHALCIDIDAE.

Spilochalcis dux, Walker.

This is the most frequent pupal parasite of *Diatraea* in British Guiana and Trinidad. In the former Colony it is usually known as *Heptasmicra curvilineata*, Cameron, which, by an examination of the types in the British Museum, is a synonym.

Spilochalcis femorata, Fabr.

In large numbers attracted to extra-floral nectaries of the mauve-flowered Leguminous cover-crop plant, *Pueraria javanica*, St. Augustine, Trinidad, in company with *Polistes canadensis* and very many *Ipobracon*, of several species.

Spilochalcis fulvescens, Ashm.

Reared from the moth, *Margaronia hyalinata*, Soledad, Cuba.

Spilochalcis sp.

Reared from *Diatraea saccharalis* larvae in rice, first by Mr. L. D. Cleare, and later by myself, in Demerara, British Guiana.

Brachymeria annulata, Fabr.

Reared from pupae of the cotton " worm " (*Anomis* (*Alabama*) *argillacea*, Hübn.), in Haiti. I am indebted to Mr. G. E. Bryant, of the Imperial Institute of Entomology, for determining this and most of the other Lepidoptera mentioned in this paper.

Brachymeria sp.

Reared from a pupa of the moth, *Mocis punctularis*, Hübn., Soledad, Cuba.

Family TORYMIDAE.

Podagrion *crassiclava*, Gahan.

Reared from a Mantid ootheca, Central Range, Trinidad.

Family EUCHARIDAE.

Kapala cuprea, Cameron.

Reared from cocoons of the large ant, *Pachycondyla crassinoda*, Latr., in Trinidad.

Family ENCYRTIDAE.

Homalotylus terminalis, Say.

Parasitising very extensively the larvae of ladybirds feeding on the cotton aphis (*Aphis gossypii*) in Haiti (undetermined ladybird) and Trinidad (*Cycloneda* sp.).

Carabunia myersi, Waterst.

Parasitising nymphs of the froghopper, *Clastoptera undulata*, in Cuba and an unreared species in Haiti. For biological observations on this extremely interesting insect see Bull. Ent. Res., xxi, pp. 341–351, 1930.

Family PTEROMALIDAE.

Neocatolaccus syrphidis, Gir.

Reared from puparia of the Syrphid, *Ocyptamus dimidiatus*, Fabr., whose larvae prey on the cotton aphis (*Aphis gossypii*), in Trinidad.

Family EULOPHIDAE.

Euplectrus platyhypenae, How.

A very common parasite of full-grown larvae of *Laphygma frugiperda*, on *Panicum maximum* and *P. barbinode* (Soledad, Cuba); and of *Cirphis* sp. on sugar-cane (Trinidad) and grasses (Trinidad).

Elachertus meridionalis, Crawf.

Reared from a small larva of the arrowroot skipper, *Calpodes ethlius*, on *Canna* sp., Soledad, Cuba.

Horismenus sp.

Reared from cocoons of *Euplectrus platyhypenae* on *Laphygma frugiperda*, Soledad, Cuba.

Tetrastichus haitensis, Gahan.

Reared abundantly from eggs of *Prepodes quadrivittatus*, Ecole Centrale d'Agriculture, Haiti.

Tetrastichus sp.

Reared from cocoons of a solitary, unreared species of *Apanteles* parasitising the larvae of *Margaronia hyalinata*, Soledad, Cuba.

Aphrostocetus fidius, Gir., and *Aphrostocetus* sp.

Reared from the cassava gall-midge, *Jatrophobia brasiliensis*, Rübs., in Trinidad. For biological observations see paper by I. H. Myers in Bull. Ent. Res., xxi, pp. 309–313, 1930.

Ootetrastichus sp.

Reared from eggs of unknown beetle on leaves of *Cordia cylindristachya*, in Trinidad.

Pseudomphale steirastomae, Gir.

A number of Chalcid larvae dissected from larvae of the cacao beetle (*Steirastoma depressum*) in Trinidad are almost certainly this species.

Aphelinus chrysomphali, Mercet.

Reared from *Aspidiotus destructor*, on coconut, Trinidad.

Family TRICHOGRAMMATIDAE.

Lathromerella sp.

Reared from eggs of the Homopteron, *Aethalion reticulatum*, on *Erythrina glauca*, Berbice, British Guiana.

Oligosita sp.

Reared from eggs of unknown leafhopper inserted in sugar-cane leaf, Trinidad.

NEW CHALCIDOID EGG-PARASITES FROM SOUTH ASIA.

By Ch. Ferrière, D.Sc.

Entomologist, Imperial Institute of Entomology.

Family Pteromalidae.

Subfamily Sphegigasterinae.

Acroclisoides indicus, sp. n. (fig. 1).

♂. Head and thorax dark metallic green ; abdomen with bluish reflections ; the short petiole black, the 2nd segment brown or more or less yellow. Antennae brown, scape and pedicel yellow. Mandibles yellowish with dark teeth. Tegulae and legs yellow, only the anterior and posterior coxae (except tip of posterior) green.

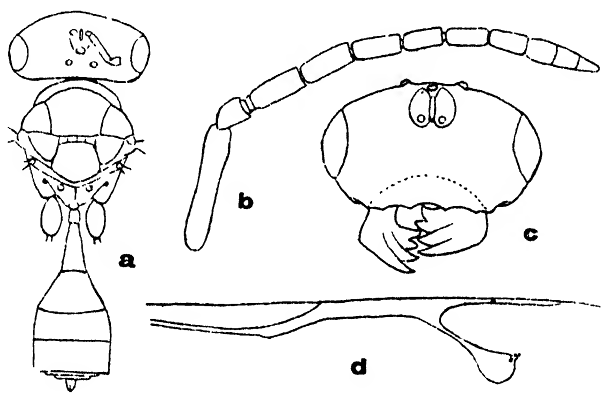

Fig. 1. *Acroclisoides indicus*, sp. n. : *a*, outline of body; *b*, antenna; *c*, head from in front ; *d*, wing nerves.

Head very large, 1·6 times as broad as the thorax ; ocelli forming a low triangle, the distance between the posterior ocelli a little shorter than between an ocellus and the eye-margin. Seen from in front the head is 1·6 times broader than long ; eyes small, rounded ; cheeks large and strongly converging ; malar space concave, with a strong tooth below and near the base of the mandibles. Clypeus not separated from the face, distinguished only by its finer reticulation, with three emarginations in front. Mandibles very large and strong, with 4 teeth. All of the head strongly and closely reticulated. Antennae inserted above the middle of the face, at the base of very short furrows. Scape reaching beyond the lateral ocelli ; pedicel short, rounded ; the two annelli very small ; funicle joints elongate, 1st about 2·5 times as long as the pedicel, the succeeding joints gradually shorter, but the 6th still twice as long as broad ; club with three joints, shorter than the two preceding joints together. *Thorax* closely reticulate like the head ; axillae with much finer reticulation, almost smooth. Pronotum very small, transverse, its posterior margin smooth ; mesonotum twice as broad as long, with complete parapsidal furrows ; scutellum rounded and convex, with a transversal groove at the base, which is curved and punctate ; middle of propodeon reticulate, with a distinct median carina and a rounded groove on each side ; the sides of propodeon almost smooth, with lateral grooves below the small rounded spiracles ; nucha rounded and small, smooth. Wings large and broad ; marginal vein not very long and somewhat thickened ; stigmal vein as long as the marginal, narrow at base and with a large knob at the end ;

postmarginal vein thin, a little longer than the marginal. Legs elongate, femora and tibiae rather thin ; hind tibiae with two spurs. *Abdomen* depressed, narrower but a little longer than the thorax, more or less triangular in outline, truncate posteriorly ; all the segments smooth. Petiole very short, much shorter than the hind coxae, almost as thick as long ; 2nd segment triangular, elongate, about as long as segments 3 and 4 together, sometimes somewhat narrower and petiole-like ; segments 3 to 5 of about equal length, twice as broad as long ; following segments very short, partly hidden by the 5th.

Length : 2·0–2·3 mm.

INDIA : Dehra Dun, U.P., 6 ♂♂, xi.1927 (*S. N. Chatterjee*).

Host. Eggs of a Pentatomid bug on a teak leaf.

Type deposited in the British Museum.

This remarkable genus is well characterised by its large head, which is much broader than the thorax and broader than long when seen from in front, by the elongate antennae with two ring-joints, the thickened marginal vein, the very short petiole, and the small triangular abdomen.

Four other species are already known, three from Australia, caught by sweeping in the jungle (Girault, Mem. Queensl. Mus., iii, 1915, p. 334), and one from the Philippines, bred from the eggs of *Tectocoris lineola*, F. (Gahan, Philipp. J. Sci., xvii, 1920, p. 345).

The position of this new species may be seen in the following key :—

1. Fore wings with an obscure dusky spot beneath knob of stigmal vein ; fourth segment occupying half of surface of abdomen ... ... *megacephalus*, Gir.
   Fore wings hyaline, fourth segment smaller 2
2. Antennae with last three funicle joints yellow, ringed with black apically *laticeps*, Gir.
   Antennae with all funicle joints equally dark 3
3. Head and thorax aeneous ; size 1·6 mm. ... ... *luzonensis*, Gah.
   Head and thorax dark metallic green ; size 2–2·5 mm. 4
4. All coxae concolorous with body ; petiole of abdomen yellow ; head only a little wider than thorax ... ... *major*, Gir.
   Middle coxae and tip of posterior coxae yellow ; petiole of abdomen black ; head much wider than thorax ... ... *indicus*, sp. n.

Agiommatus acherontiae, sp. n.

♀. Head and thorax bluish green ; abdomen aeneous brown above, with two yellowish transverse stripes, one covering the end of the 2nd and the base of the 3rd segment, the second narrower, between the 4th and 5th segments ; ventral side of abdomen almost entirely yellow. Antennae yellowish brown, scape and pedicel clearer. Mandibles yellow with brown teeth. Legs entirely clear yellow, except the base of the anterior and posterior coxae which are greenish.

Head transverse, broader than the thorax, finely reticulate ; eyes strongly converging above, the face below the antennae twice as broad as the vertex ; cheeks broader than half the length of the eye, very finely reticulate, almost smooth. Ocelli rather large, the lateral ones nearer to the eye-margin than their own breadth, the distance to the front ocellus about as long as the diameter of an ocellus. Mandibles strong, with two small teeth. Antennae short ; scape narrow, not reaching to the front ocellus ; pedicel a little longer than broad ; three small transverse annelli ; funicle joint 1 about 1·5 times as long as broad, 2 and 3 only slightly elongate, 4 and 5 almost quadrate ; club as long as the two preceding joints together. *Thorax* more strongly and more closely reticulated than the head. Pronotum transverse, short,

sharply angulated along its front margin ; mesonotum more than twice as broad as long, the parapsidal furrows only anteriorly weakly impressed ; mesopleurae with an elongate impressed area, which is strongly punctate, the remainder smooth. Scutellum more finely reticulate posteriorly than anteriorly ; axillae very finely striate, almost smooth. Propodeon with the usual cross formed by the median longitudinal and transverse carinae ; the four areae thus formed finely reticulate ; nucha rounded and smooth. Wings large, marginal vein much shorter than the submarginal, 2·5 times as long as the stigmal vein ; postmarginal vein longer than the stigmal. Legs slender. *Abdomen* narrower but a little longer than the thorax, oval ; petiole a little shorter than the hind coxae, twice as long as broad ; segment 2 about as long as its hind margin, 3 shorter, its hind margin emarginate and angulate in the middle. Ovipositor not protruding.

♂. The single male is much smaller, but similar to the female. Antennae quite yellow, only the club brownish ; funicle joints not longer than broad. Abdomen a little shorter than the thorax, with a yellow spot in the middle extending on the end of the 3rd and base of the 4th segments.

Length : ♀ 2·3–2·5 mm. ; ♂ 1·4 mm.

INDIA : Dehra Dun, U.P., 2 ♀♀, 1 ♂, v.1928 (*S. N. Chatterjee*).

Host. Eggs of *Acherontia styx*, Westw.

Type deposited in the British Museum.

This species is closely related to *A. attaci*, Ferr., from which it differs in its smaller size, the more yellowish coloration of the legs, tegulae and scape, and other characters given in the key below. Another species received from the MALAY PENINSULA, Kuala Lumpur (*W. A. Lamborn*), bred from eggs of an unknown moth on a wild plantain leaf, agrees exactly with the description of *A. sumatraensis*, Crawf.

The three known species of this genus may be distinguished as follows :—

1. Abdomen dark brown ; legs, including coxae, entirely whitish yellow ; anterior coxae with a distinct spine in front ; antennae with 1st funicle joint a little longer than broad, the others more or less quadrate ; size 2·25 mm. *A. sumatraensis*, Crawf.
   Abdomen with two yellow transverse stripes ; hind coxae more or less green ; anterior coxae without spine 2
2. Antennae with first funicle joint twice as long as broad, the succeeding joints gradually shorter, but all longer than broad ; legs whitish, all coxae entirely green ; size ♀ 3–3·5 mm. ... ... *A. attaci*, Ferr.
   First funicle joint a little longer than broad, the others shorter, the 4th and 5th quadrate ; legs more yellowish, only the base of anterior and posterior coxae green ; size ♀ 2·3–2·5 mm. ... ...*A. acherontiae*, sp. n.

Family ENCYRTIDAE.

Subfamily ENCYRTINAE.

Genus **Ooencyrtus,** Ashmead.

Many species of these egg-parasitising Encyrtids are already known from all over the world, but especially from Europe and America. They are economically very important, as they destroy the eggs of several noxious Lepidoptera, and in some instances also those of Heteroptera, PENTATOMIDAE. One species, *Ooencyrtus* (*Schedius*) *kuwanae*, How., a parasite of the eggs of *Porthetria* (*Lymantria*) *dispar*, has been introduced from Japan into the United States of America, and from there lately into Morocco and Spain.

We are of the opinion that the genus *Schedius*, Howard, is to be considered a synonym, or at most a subgenus, of *Ooencyrtus*. In large series of the same species the axillae may be united or more or less separated in the middle, this depending upon the position of the mesonotum. Gahan, in his description of *Schedius podontiae* (Konowia, iii, 1922, p. 51), says: "The axillae meeting in the middle but the points of union in some instances covered by the overlapping posterior margin of the mesoscutum, the question of whether the axillae are separated or not depending upon the position in which the specimen died." We have observed this to be the case in all our series of species. As for the thickening of the marginal vein, this character seems to be lacking in the Oriental species, as Mercet has already pointed out.

From South Asia five species of *Ooencyrtus* (*Schedius*) have already been described, and we are able to add four new species from the Malay Peninsula and Java. The nine species thus known may be separated as follows:—

1. Thorax orange, pronotum and mesonotum apically and axillae white; club of antenna as long as the short funicle ... ... *pyrillae*, Crawf.
   Thorax black or brown, with metallic reflections; club as long as the last 3 or 4 funicle joints together 2
2. Abdomen more or less yellow 3
   Abdomen quite black 5
3. Abdomen only yellow at base; thorax greenish black; funicle joints 1–3 subquadrate, 4–6 longer than broad ... ... *malayensis*, sp. n.
   Abdomen quite yellow 4
4. Head and thorax aeneous black; legs yellow, funicle joints 1–3 or 4 a little longer than thick ... ... *papilionis*, Ashm.
   Thorax brownish, pleurae yellow like the abdomen; legs whitish; funicle joints 1–2 subquadrate, 3–5 a little longer than broad, 6 larger and quadrate *leucocerus*, Merc.
5. Legs entirely yellow ... ... *erionotae*, sp. n.
   Femora more or less brown 6
6. All funicle joints longer than broad; scape scarcely thickened in middle; size 1·4–1·5 mm. ... ... *major*, sp. n.
   First funicle joints at least short, not or but little longer than broad; scape slightly but distinctly enlarged beneath the middle; size smaller, 0·8–1 mm. 7
7. Funicle joints 1–2 small, quadrate, 3–6 longer than broad; club as long as 3 preceding joints together; scutellum generally shining green, especially at tip ... ... *corbetti*, sp. n.
   All funicle joints subquadrate or very little longer than broad; club about as long as 4 preceding joints together; scutellum black or brown 8
8. Scutellum with fine close punctation over whole surface; all coxae and femora black, trochanters, base and apex of femora and all tibiae and tarsi pale yellowish ... ... *podontiae*, Gah.
   Scutellum reticulated on basal half, smooth and shining on apex; legs whitish yellow, middle of femora slightly darkened ... ... *javanicus*, Merc.

Ooencyrtus malayensis, sp. n. (fig. 2, *d*).

♀♂. Body black with metallic green reflections on the head and the thorax, more purple on the pleurae; abdomen aeneous brown, with a broad transverse yellow stripe on the base. In the male the thorax is more bronze and the abdomen is not yellow at base. Antennae yellow, with the basal half of scape and base of pedicel brownish. Legs entirely yellow.

♀. *Head* transverse, rounded in front. Vertex finely punctate, narrow, as broad as the length of the pedicel with two following joints united. The lateral ocelli nearer to each other than to the front ocellus, situated very near the eye-margin. Frons longer than broad. Antennae inserted at the base of the face, near the clypeus ; scape short, reaching only to the base of the front, slightly expanded in the middle ; pedicel elongate, two-fifths the length of the scape and more than twice as long as broad ; funicle joints 1–3 small, subquadrate, not much longer than one-third of the pedicel ; joints 4–6 longer than broad, each distinctly longer than each of the three basal joints ; club 3-jointed, not much broader than the funicle, a little longer than the 3 preceding joints united. *Thorax* finely reticulate, mesonotum more shining than the scutellum. Mesonotum wider than long ; scutellum rounded ; axillae generally separated, propodeon very short. Wings large, longer than the body ; marginal vein punctiform, very little longer than broad ; stigmal vein twice as long as the marginal ; post-marginal vein shorter than the stigmal. *Abdomen* triangular, shorter than the thorax, depressed above ; ovipositor not or very little protruding.

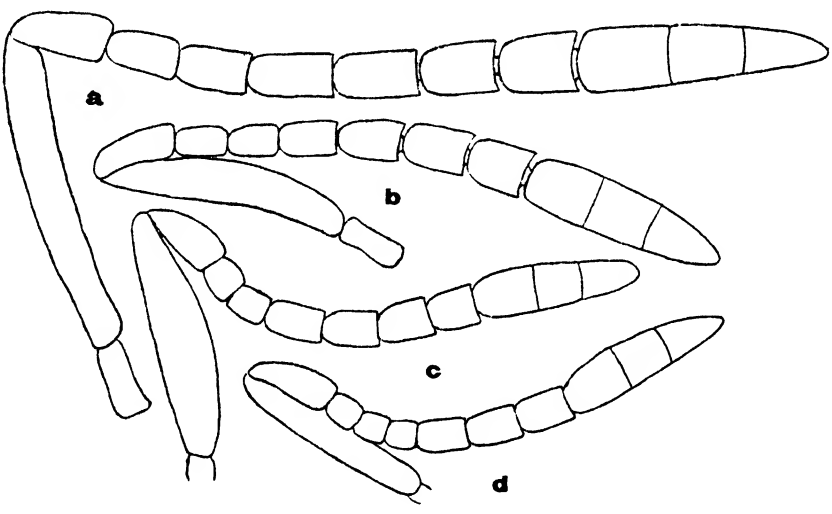

Fig. 2. Antennae of : *a, Ooencyrtus major*, sp. n. ; *b, O. erionotae*, sp. n. ; *c, O. corbetti*, sp. n. ; *d, O. malayensis*, sp. n.—all on same scale.

♂. Smaller. Antennae narrower ; scape short, about as long as the pedicel and two following joints united ; pedicel small, rounded ; funicle joints about twice as long as broad, covered with a few long ciliae ; club oval, covered with small ciliae. Abdomen much shorter than the thorax.

Length : ♀, 0·7–0·8 mm. ; ♂, 0·5–0·6 mm.

MALAY PENINSULA : Johore, 19 ♀♀, 5 ♂♂, i.1929 ; Kuala Lumpur, 4 ♀♀, iii.1925, 1 ♀, ii.1929 ; Setapak, 6 ♀♀, 2 ♂♂, xii.1922 (*G. H. Corbett*) ; Kuala Lumpur, 3 ♀♀, 1 ♂, i.1921 (*W. A. Lamborn*).

Hosts. Eggs of *Cephanodes hylas*, L., *Papilio agamemnon*, L., *P. polytes*, L., and an unknown Lepidopteron ; also eggs of *Leptocorisa acuta*, Thbg. (Setapak).

Type deposited in the British Museum.

This species is closely related to *O. papilionis*, Ashmead, but the abdomen is only yellow at the base and the last three funicle joints are longer.

Ooencyrtus corbetti, sp. n. (fig. 2, *c*).

♀♂. Aeneous black with some greenish reflections on face, mesonotum, and base of abdomen; scutellum more shining green, especially at the tip, and more or less purple at the base. Antennae yellow, the basal half of scape and base of pedicel brownish. Legs yellow, coxae and middle of femora brown, the hind femora almost entirely dark.

♀. *Head* a little narrower than the thorax, rounded in front; seen from above about 3 times as broad as long. Vertex and frons narrow, with breadth two-thirds the length of the scape, finely shagreened. Lateral ocelli situated near the eye-margin, nearer to each other than to the median ocellus. Antennae inserted at the base of the face; scape short, slightly expanded in the middle; pedicel elongate, one-third the length of the scape; the first two funicle joints subquadrate, together about as long as the pedicel; the four following joints larger, a little longer than broad; club oval, broader than the funicle, as long as 3 preceding joints together. *Thorax* with mesonotum broad, finely reticulate, almost smooth; scutellum closely punctate all over, except at the extreme end; axillae separated in the middle; propodeon very short. Wings large, longer than the body; marginal vein punctiform, very little longer than broad; sigmal vein short, rounded at tip, about as long as marginal and postmarginal veins together. *Abdomen* small, triangular or rounded, much shorter than the thorax; ovipositor not protruding.

♂. Smaller, differing only in the form of the antennae, which are filiform, with the pedicel short and rounded, and the funicle joints all a little longer than broad, covered with long ciliae.

Length: ♀, 0·9–1 mm.; ♂, 0·8 mm.

MALAY PENINSULA: Kuala Lumpur, 11 ♀♀, 1 ♂, vii.1921 (*G. H. Corbett*).

Host. Eggs of *Podontia 14-punctata*, L.

Type deposited in the British Museum.

Very near *Schedius podontiae*, Gahan, but, from Gahan's description, we believe them to be different. The proportions of the antennal joints are not alike, the last four funicle joints in *O. corbetti* being distinctly larger than the first two joints, if not always as elongate as in our drawing, and the club is never longer than the 3 preceding joints together. Furthermore, the scutellum has a characteristic green colour on its posterior half, more or less strong but always different from that of the rest of the thorax; and the tip of the scutellum is smooth.

Ooencyrtus erionotae, sp. n. (fig. 2, *b*).

♀♂. Black with some faint greenish reflection on face and thorax. Antennae yellow, base of scape and of pedicel brownish. Legs entirely yellow.

♀. *Head* as broad as the thorax; vertex and frons very narrow, about as broad as the pedicel with half the next joint united. Ocelli situated near the eye-margin, nearer to each other than to the front ocellus. Antennae inserted near the clypeus; scape narrow, not much broadened below the middle; pedicel elongate, one-third the length of the scape; funicle joints subequal in length, the first generally longer than broad, the last more or less quadrate; club not much broader than the funicle, longer than the 3 preceding joints together. *Thorax* oval, not much longer than broad, finely reticulate; scutellum rounded, more closely punctate except at the end, where it is smooth and shining; axillae smooth, generally meeting in the middle. Wings large; marginal vein punctiform, about as long as broad; postmarginal vein not much longer than the marginal; stigmal vein a little longer than marginal and postmarginal veins together. *Abdomen* shorter than the thorax, rounded; ovipositor not protruding.

♂. Smaller, but similar ; antennae elongate, filiform ; scape as long as the pedicel with 3 following joints united ; pedicel small, rounded ; funicle joints rounded, little longer than broad, covered with long ciliae. Abdomen smaller than the thorax, triangular.

Length : ♀, 0·8–1 mm. ; ♂, 0·6–0·9 mm.

MALAY PENINSULA : Sungei Tua, 4 ♀♀, vii.1928 (*G. H. Corbett*) ; Kuala Lumpur, 21 ♀♀, 6 ♂♂, i.1921 (*W. A. Lamborn*).

Hosts. Eggs of *Erionota thrax*, L., and of an unknown Lepidopteron on wild plantain leaf.

Type deposited in the British Museum.

This species is characterised by its quite yellow legs, with dark abdomen. The funicle joints are not always, in dry specimens, so elongate as in our drawing, their thickness varying while their length remains more or less the same.

Ooencyrtus major, sp. n. (fig. 2, *a*).

♀♂. Black with greenish reflection on the thorax, especially the tip of scutellum, and on the abdomen, more bluish on the face. Antennae of female brown, scape and pedicel dark brown, only the extreme tip yellow ; antennae of male yellow, base of scape and pedicel brown. Legs yellow, coxae, front femora almost entirely, and basal half of hind femora, brown ; centre of middle femora above and base of all tibiae slightly brownish. The male has the femora less brown and the middle femora quite yellow, but the middle tibiae are more brownish. Sheaths of ovipositor yellow.

♀. *Head* transverse, rounded in front, very finely shagreened, almost smooth. Lateral ocelli situated near the eye-margin and a little nearer to each other than to the front ocellus. Antennae inserted near the clypeus ; scape narrow, not or very little expanded below the middle ; pedicel elongate, but shorter than one-third the length of the scape ; funicle joints subequal in length, broadening toward apex, all longer than broad, except the 6th, which is more or less quadrate ; club elongate, a little longer than the 3 preceding joints together. *Thorax* reticulate, the scutellum not so strong as the mesonotum ; axillae united in the middle, or sometimes separated by the overlapping mesonotum. Wings as long as the body ; marginal vein punctiform, not or little longer than broad ; postmarginal vein very short ; stigmal vein narrow, a little longer than marginal and postmarginal veins united. *Abdomen* small, triangular, shorter than the thorax ; ovipositor slightly protruding.

♂. Smaller. Antennae filiform ; pedicel little longer than broad ; funicle joints all about twice as long as broad, the 3rd the longest, all covered with short ciliae. Abdomen small, triangular.

Length : ♀, 1·4–1·5 mm. ; ♂, 1–1·1 mm.

JAVA : Buitenzorg, 11 ♀♀, 3 ♂♂, vii.1925 (*R. Menzel*).

Host. Eggs of *Attacus atlas*, F.

Type deposited in the British Museum.

From the eggs of the same host were also bred the Eupelmid, *Anastatus menzeli*, Ferr., with its var. *obscurus*, Ferr., the Pteromalid, *Agiommatus attaci*, Ferr., and a species of *Tetrastichus*.

This *Ooencyrtus* may be distinguished from the other species by its larger size, its narrower scape, and its funicle joints all longer than broad (except sometimes the 6th).

The other Asiatic species mentioned in our key are :—

***Ooencyrtus papilionis*, Ashmead.**

Ooencyrtus papilionis, Ashmead, Canad. Entom., xxxvii, 1905, p. 4.
PHILIPPINES ISLANDS : Manila, from eggs of *Papilio* sp.

O. pyrillae, Crawf.

Ooencyrtus pyrillae, Crawford, Insec. Insc. Menstr., iv, 1926, p. 101.
INDIA : Pusa, from eggs of *Pyrilla aberrans.*

O. podontiae, Gahan.

Schedius podontiae, Gahan, Treubia, iii, 1922, p. 51.
JAVA : Buitenzorg, from eggs of *Podontia affinis*, Grond.

O. leucocerus, Merc.

Ooencyrtus (Schedius) leucocerus, Mercet, Bol. R. Soc. esp. Hist. nat., xxii, 1922, p. 150.
JAVA : Soekaboemi, from eggs of an unknown Lepidopteron.

O. javanicus, Merc.

Ooencyrtus (Schedius) javanicus, Mercet, loc. cit., p. 152.
JAVA : Soekaboemi, from eggs of a Lepidopteron.

Subfamily APHELININAE.

Centrodora idioceri, sp. n.

♀♂. Body of female entirely orange-yellow, only the eyes and ocelli reddish black. Male yellowish, thorax more or less brown above.

♀. *Head* brown, rounded in front, seen from above about twice as broad as long ; ocelli forming a regular triangle, distance of posterior ocelli from the eye-margin equal to their own diameter; eyes rounded. Seen from in front the head is as long as broad, the cheeks as long as the eyes. Antennae inserted near the clypeus ; scape narrow, reaching to the middle of the frons ; pedicel elongate, not broader than and half as long as the scape, a little more than twice as long as broad ; the first two funicle joints subequal in length, small, transverse ; the second a little broader than the first and about twice as broad as long ; 3rd funicle joint broader and longer, a little shorter than the pedicel ; club entire, as broad as the 3rd funicle joint and more than twice as long, not quite so long as the scape. The length of the joints in 1/1000 mm. is : 80, 40, 8, 8, 33, 73. *Thorax* oval, finely shagreened ; mesonotum with complete parapsidal furrows ; scutellum broader than long, propodeon a little shorter than the scutellum, with a median carina. Wings slightly infuscate, yellowish, with a faintly darker cloud under the base of the marginal vein ; submarginal vein as long as the marginal vein, which is somewhat thickened ; stigmal vein very short, little longer than the breadth of the marginal vein. Marginal ciliae short, a little longer near the lower end ; discal ciliation short, the ciliae situated before the oblique line longer and sparser. Hind wings with a conspicuous line of ciliae below the upper margin and a second line, less visible, near the lower margin. Legs short, slightly thickened. *Abdomen* about twice as long as the thorax, pointed at tip. Ovipositor slightly protruding.

♂. Similar ; antennae with the scape somewhat broadened in the middle, the joints proportionately as long as in the female, only the two first funicle joints more rounded, about as long as broad, and together almost as long as the third. Abdomen only a little longer than the thorax.

Length : ♀♂, 0·6–0·7 mm.

JAVA : Buitenzorg, 12 ♀♀, 2 ♂♂, vi.1928 (*Dr. S. Leefmans*). All on microscope slides.

Host. Eggs of *Idiocerus niveosparsus*, Leth. (Hem. Jassidae), on mango twigs.

Type deposited in the British Museum.

This is the first species known from Asia. In the key given by Waterston (Bull. Ent. Res., viii, 1927, p. 52), it is most nearly related, in its coloration, to *C.* (*Paraphelinus*) *australiensis*, Gir., but it differs distinctly from that species judging by Girault's short description (Arch. f. Naturg., lxxix, A6, 1913, p. 74). The main differences are :

C. australiensis, Gir. Pedicel much longer than the 3rd funicle joint,* which is only about one-third the length of the club ; 2nd funicle joint distinctly more than half the length of the 3rd. Wings hyaline ; hind wings near the tip with about 5 lines of discal ciliae.

C. idioceri, sp. n. Pedicel only a little longer than the 3rd funicle joint, which is almost half as long as the club ; 2nd funicle joint less than a quarter the length of the 3rd. Wings slightly infuscate ; hind wings with only 2 lines of discal ciliae.

This new species differs, moreover, from the other known species in its two very small, more or less transverse, basal funicle joints.

The males of three species are now known, and may be distinguished by the relative lengths of the antennal joints. *C. xiphidii*, Perkins, has the first two funicle joints very short and broad, together much shorter than the 3rd, which is nearly equal to the club. *C. perkinsi*, Watst., has the first two funicle joints cylindrical, a little longer than broad, together longer than the 3rd joint, which is less than a third of the club. *C. idioceri*, sp. n., has the first two funicle joints rounded, together not quite so long as the 3rd, which is more than a third of the club.

Family EULOPHIDAE.

Subfamily ENTEDONINAE.

Pareuderus, gen. nov.

Head transverse, narrow. Antennae 10-jointed, with one annellus, a 4-jointed funicle and a 3-jointed club. Thorax with a very short pronotum ; mesonotum with strong parapsidal furrows ; scutellum convex, protruding over the postscutellum ; propodeon short, oblique, with a median carina. Wings with a long marginal vein and short postmarginal and stigmal veins, the former a little longer than the latter. Discal ciliation weak, arranged in regular rows and with a few longer hairs below the middle of the marginal vein. Abdomen short, oval, with a long ovipositor, about as long as the abdomen.

This genus is very similar to *Euderus*, Hal., in the form of the antennae and of the wings. It differs greatly however in the form of the abdomen. This in *Euderus* is much elongate and pointed, longer than the head and thorax united, and with the ovipositor not or little protruding ; in *Pareuderus* it is short, oval, not longer than the thorax and with a long ovipositor.

Pareuderus torymoides, sp. n. (fig. 3, *c*, *d*, *e*).

♀♂. Head and thorax black, with some bluish reflections, or sometimes greenish on the thorax of the males ; abdomen dark greenish or bluish, violet on the sides. Antennae dark brown, pedicel with bluish shine, underside of scape yellow. Legs with bluish coxae and femora, the tibiae brown, slightly bluish in the middle, the tip of tibiae and the tarsi white, except the last tarsal joint which is brown. Ovipositor sheaths brown.

* Girault calls this joint the "proximal club joint," as the antennae have, for him, a 2-jointed funicle and a 2-jointed club. We follow Howard, Waterston, Mercet and others, and consider the antennae as having a 3-jointed funicle and a solid club.

♀. *Head* narrow, very transverse, the vertex thin; ocelli placed almost on a line, the lateral nearer to the eye-margin than their own diameter. Below the front ocellus a transverse furrow stretches almost from one eye to the other, separating the vertex from the frons. Face shagreened, slightly convex, the antennal groove not deep and without marginal carinae. Between the base of the antennae and the mouth are two narrow furrows; clypeus small and not distinctly delimited; cheeks with length one-third the length of an eye. Mandibles with 3 teeth. Antennae inserted in the middle of the face; scape narrow, reaching to the front ocellus; pedicel not broader than and as long as a third of the scape; annellus very small, transverse; the 4 joints of the funicle subequal in length and as long as the pedicel, the 1st a little shorter than the 2nd, the 4th a little longer than the others, all slightly longer than broad; club longer than the two preceding joints together, pointed at tip. *Thorax* entirely punctate, dull, the scutellum and the pleurae more finely punctate than the mesonotum. Median lobe of mesonotum convex, the parapsidal furrows deep; scutellum not higher than the mesonotum, but strongly convex on the sides and behind; postscutellum hidden under the tip of the scutellum; propodeon short, punctate, with a median carina and short furrows near the spiracles. Wings

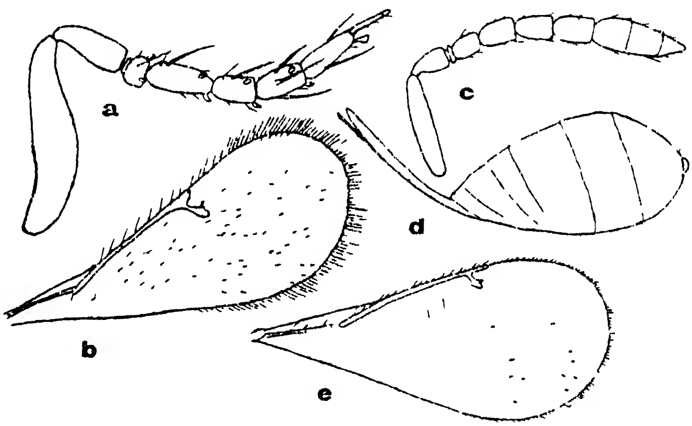

Fig 3 *Achrysocharis promecothecae*, sp n *a*, antenna of ♀; *b*, fore wing. *Pareuderus torymoides*, gen. et sp n *c*, antenna of ♀; *d*, abdomen, *e*, fore wing

large, reaching to the middle of the ovipositor, hyaline, very transparent; marginal vein longer than the submarginal, gradually and slightly narrowed toward the apex; postmarginal vein thin, as long as one-fourth of the marginal; stigmal vein shorter than the postmarginal, shortly petiolate. Marginal ciliae very short; discal ciliae small, arranged in about ten more or less regular lines, which extend only beyond the stigmal vein; the rest of the wing without ciliation except two or three longer ciliae under the marginal vein. Legs rather short; hind coxae irregularly and shortly denticulate along the upper margin; femora and tibiae covered with some scattered white hairs, forming a regular row along the posterior margin of the hind tibiae. *Abdomen* smooth, as long as the thorax, but short, a little compressed laterally, not petiolate, the segments subequal in length. Ovipositor with the sheaths slightly ciliate, about as long as two-thirds the abdomen.

♂. Similar, but antennae shorter and narrower; thorax a little narrower, with the scutellum more convex at the sides and behind; abdomen oval, narrow, also a little compressed laterally and as long as the thorax.

Length: ♀, 1·5–1·6 mm. (without ovipositor); ♂, 1·2–1·4 mm.

JAVA: Buitenzorg, 24 ♀♀, 16 ♂♂, vi.1929 (*Dr. S. Leefmans*).

Host. Eggs of *Alcides leeuweni*, Hllr. (CURCULIONIDAE), on *Ceiba pentandra*. *A. leeuweni* is a pest of cacao and kapok.

Type deposited in the British Museum.

Achrysocharis promecothecae, sp. n. (fig. 3, *a*, *b*).

♀♂. Head and thorax shining green, more or less bluish, especially on the sides of the thorax; abdomen aeneous. Antennae yellow, slightly brownish at apex, scape and pedicel clearer. Legs entirely yellow, except the hind coxae, which are concolorous with the thorax. Wings hyaline, with a faint cloud below the stigma.

♀. *Head* small, transverse, finely punctate; frons and face often much sunken after death. Ocelli forming a low triangle; the lateral ocelli nearer to the eye-margin than to each other. Seen from in front the head is rounded, the cheeks about as long as the eyes. Antennae inserted a little under the middle of the face, with 8 joints; scape elongate, reaching to the ocelli; pedicel more than twice as long as broad, as long as three-eighths of the scape; one small annellus; funicle with 3 joints, the 1st short, broader than long, about as long as one-third of the pedicel, 2nd elongate, almost as long as the pedicel, 3rd a little shorter than the 2nd, but still longer than broad; club with 2 joints, about as long as the funicle, 1st joint somewhat longer than the 3rd funicle joint, 2nd as long as the 2nd funicle joint, ending in a long spur-like protuberance, which is as long as three-fourths the length of the joint itself. Each joint bears some long thick ciliae, and near their apex small bladder-like appendages or sense-organs similar to those found on the antennae of certain *Trichogramma*, but larger. *Thorax* oval, almost flat above, finely punctate; pronotum very small, transverse; mesonotum almost twice as broad as long, with complete, but weak, parapsidal furrows; scutellum rounded, flat; propodeon short, more shining, with a median carina. Wings broadly rounded at the end, with rather long marginal ciliae, and numerous irregularly placed discal ciliae, except for a short row running from the knob of the stigma to the upper end of the wing, and a longer row above the lower margin of the wing. Marginal vein long and thin; stigmal vein narrow, about as long as one-fourth the marginal vein; postmarginal vein very short. Hind wings narrow, pointed at apex, the marginal ciliae at the end of the lower margin as long as the greatest breadth of the wing. Legs narrow, short, hind femora a little thickened. *Abdomen* short, oval, depressed, not longer than the thorax, the segments subequal in length; ovipositor not protruding.

♂. Very similar to the female, but smaller; antennae narrower and relatively longer.

Length: ♀, 0·7 mm.; ♂, 0·6 mm.

JAVA: Poerwaredjo, 5 ♀♀, 1 ♂, iii.1930 (*R. W. Paine*).

Host. Eggs of *Promecotheca* sp. (HISPINAE), on coconut.

Type deposited in the British Museum.

This species is very similar to *A. leptocerus*, Waterston, obtained in West Africa, Gold Coast, from the eggs of another Hispid, *Coelaenomenodera elaeidis*, Maul. (Bull. Ent. Res., xv, 1925, p. 393). It differs especially in the following characters:

A. leptocerus, Watst. Blackish brown, with dark green metallic reflections on vertex and thorax; legs pale, with coxae mainly brown and femora brown-streaked above. Antennae with pedicel not quite twice as long as broad, 1st funicle joint subquadrate, the other antennal joints (except the last) subequal in length, a little shorter than the pedicel.

A. promecothecae, sp. n. Head and thorax shining green, abdomen aeneous; legs entirely yellow, except coxae. Antennae with pedicel more than twice as long as broad; 1st funicle joint broader than long, the 2nd joint as long as the pedicel, the 3rd distinctly shorter, as long as the 1st club-joint.

Many other species are known in the genus *Achrysocharis*, Gir., most of which have been described by Girault from specimens swept from herbage in Australia. Others are parasitic on small Diptera ; but it is most probable that species belonging to more than one genus are actually united under the name *Achrysocharis*.

Subfamily Tetrastichinae.

Tetrastichus schoenobii, sp. n. (fig. 4, *a*, *b*, *c*).

♀♂. Body shining green with some bluish reflections. Antennae brown, scape yellow. Legs entirely yellow (except the base of anterior coxae and the greater part of the hind coxae, which are greenish).

♀. *Head* transverse, very short behind the eyes ; ocelli forming a low triangle with the stemmaticum convex, the lateral ocelli a little nearer to the eye-margin than to each other, and united to the eye-margin by a thin furrow. Antennal furrow broad and not deep. Eyes almost rounded, cheeks as long as the transverse breadth of an eye, crossed by a furrow which stretches from the base of the eye to the mandible. Antennae inserted in the middle of the face ; scape short, reaching scarcely to the front ocellus ; pedicel elongate, a little shorter than half the length of the scape ; 2 annelli, the 1st very small ; the 3 funicle joints much elongate, three times as long as broad and about twice as long as the pedicel, subequal in length ; club with 3

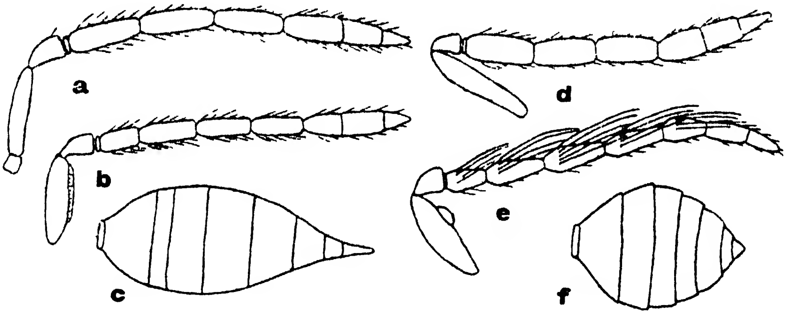

Fig. 4. *Tetrastichus schoenobii*, sp. n. : *a*, antenna of ♀ , *b*, antenna of ♂ ; *c*, abdomen. *T. gardneri*, sp. n. : *d*, antenna of ♀ , *e*, antenna of ♂ ; *f*, abdomen.

joints, narrow and elongate, almost as long as the two preceding joints together ; all the joints covered with short ciliae. *Thorax* smooth and shining, very finely shagreened. Mesonotum with deep parapsidal furrows and the median furrow very weak, nearly obliterated anteriorly ; scutellum as long as the mesonotum, with the two longitudinal furrows thin, but well marked ; propodeon finely rugulose, dull, with a median carina and lateral carinae just before the spiracles, which are small and rounded. Wings large, reaching beyond the tip of the abdomen ; submarginal vein with a single hair ; marginal vein longer than the submarginal ; stigmal vein very thin at the base, slightly broadening toward the end, where it is broader than the marginal vein ; its length is about one-third that of the marginal vein ; marginal ciliae short. Legs narrow, normal. *Abdomen* elongate, oval, pointed behind, not broader than the thorax and a little longer than head and thorax together. Ovipositor slightly protruding.

♂. Similar, smaller ; antennae narrower, the 1st of the 4 funicle joints smaller than the others, about as long as the pedicel ; funicle and club covered with short ciliae ; the sensorial organ on the scape narrow and elongate, almost as long as the scape itself ; abdomen oval, a little longer than the thorax.

Length : ♀, 1·1–1·6 mm. ; ♂, 0·8–1·2 mm.

MALAY PENINSULA: Setapak, vi.1929, 30 ♀♀, 4 ♂♂; Sungar Siakap, iii.1930, 14 ♀♀, 10 ♂♂; Gombak Selangor, 32 ♀♀, 4 ♂♂ (*G. H. Corbett*). SIAM: Bangkok, xii.1929, 12 ♀♀, 3 ♂♂ (*W. R. S. Ladell*). CEYLON: Jaela, ix. 1926, 14 ♀♀, 6 ♂♂ (*J. C. Hutson*).

Hosts. Eggs of *Schoenobius bipunctifer*, Wlk. (*incertellus*, Wlk.) (Malaya and Siam) and of *Spodoptera mauritia*, Boisd. (Malaya and Ceylon).

Type deposited in the British Museum.

This seems to be an important parasite of the rice-borers and has already been mentioned in the literature on rice pests as *Tetrastichus* sp. It is associated in the eggs of *Schoenobius* with two or three species, or forms, of *Trichogramma* and with the Scelionid, *Phanurus beneficiens*, Zehnt.

Tetrastichus gardneri, sp. n. (fig. 4, *d, e, f*).

♀♂. Dark green, in some parts more or less aeneous. Antennae brown, scape yellow; the entire antenna more yellow in the male. Legs entirely yellow, except the coxae which are concolorous with the thorax.

♀. *Head* transverse, finely shagreened, almost smooth. The posterior ocelli nearer to the eye-margin than to each other, with a small furrow between the ocelli and the eyes. Seen from in front the head is rounded; cheeks as long as the transverse diameter of an eye, with a weak longitudinal furrow. Antennae inserted in the middle of the face, scape narrow, reaching to the front ocellus; pedicel short, a little longer than broad; two small annelli; funicle joints elongate, broader than and more than twice as long as the pedicel, about twice as long as broad, the 1st somewhat longer than the two others; club pointed at the end, as long as the two preceding joints together; funicle and club covered with small white ciliae. *Thorax* oval, finely shagreened. Mesonotum large, with the parapsidal and median furrows well marked. Scutellum shorter than the mesonotum, very convex, with strong longitudinal furrows. Propodeon short, almost smooth, with a median and lateral carinae. Wings large, reaching far beyond the end of the abdomen; submarginal vein with 2 or 3 ciliae; marginal vein long and narrow; stigmal vein also narrow, the knob very small; it is about as long as one-fourth of the marginal vein. *Abdomen* small, rounded, as broad as the thorax but shorter; segments nearly subequal in length. Ovipositor not protruding.

♂. Similar, differing only in the form of the antennae, which are thin, with the 1st funicle joint scarcely longer than the pedicel, the 3 others elongate, and the club as long as two preceding joints together; all funicle joints and the 1st club-joint bear near the base a half circle of long ciliae, each longer than the joint itself; sense-organ on the scape small and rounded. Abdomen oval, narrower but not much shorter than the thorax.

Length: ♀, 1·2–1·5 mm.; ♂, 1–1·2 mm.

INDIA: Dehra Dun, U.P., 27 ♀♀, 5 ♂♂, x.1927 & iii–iv.1928 (*S. N. Chatterjee*).

Host. Eggs of PENTATOMIDAE on teak. From the same eggs were also bred the *Acrochsoides indicus* described above (xi.1927), an Eupelmid, which we identify as *Anastatus colemani*, Crawf., and 3 ♂♂ of another species of *Tetrastichus*.

Few *Tetrastichus* spp. are yet known as egg-parasites. In Asia we know only *Tetrastichus pyrillae*, Crawf., from the eggs of *Pyrilla aberrans* in India, and *T. australasiae*, Gahan, from eggs of cockroaches in Java. But as many *Tetrastichus* are hyperparasites, it is not impossible that the same species may be in some instances bred both from eggs of one host and from larvae of another; we have, for instance, an undescribed species from Java bred from eggs of *Attacus atlas*, which seems identical with other specimens bred from larvae of *Euproctis* sp.

Tetrastichus egg-parasites must not be confused with species of *Ootetrastichus*, Perk., which are parasites in the eggs of leafhoppers (DELPHACIDAE, FULGORIDAE, etc.). This last genus differs specially from *Tetrastichus* in the antennae having 4 annelli and only a two-jointed club.

Family TRICHOGRAMMATIDAE.

Abbella mariellae, sp. n. (fig. 5, *a*, *b*, *c*).

♀♂. Body brownish black, pleurae brown, middle of postscutellum and propodeon yellow. Antennae pale brown, scape and tip of club yellowish. Wings hyaline, slightly infumate beyond the marginal vein along the anterior margin of the wing. Legs with the coxae and femora brown, the trochanters, knees, tibiae and tarsi yellow. The male has the head and the sides of the thorax paler, the antennae and legs almost entirely yellow.

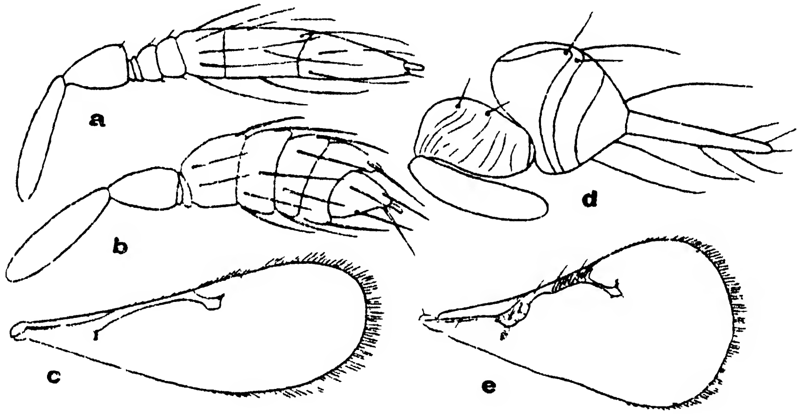

Fig 5 *Abbella mariellae*, sp n *a*, antenna of ♀, *b*, antenna of ♂, *c*, fore wing *Haeckeliana brontispae*, sp n *d*, antenna of ♀, *e*, fore wing

♀. *Head* small, very transverse, ocelli in a very low triangle ; seen from in front, the head is a little longer than broad, the cheeks as long as the eyes. Antennae inserted a little below the middle of the face ; scape narrow, reaching to the front ocellus ; pedicel triangular, about as long as half the scape and about 1·5 times as long as broad ; two small transverse annelli ; the two funicle joints small, about as long as one-third of the pedicel and narrower, rounded, a little longer than broad ; club with 3 joints, very elongate, as long as scape, pedicel and funicle united ; 1st joint as long as the funicle, a little broader than long, 2nd and 3rd joints subequal in length, longer than broad, the 3rd pointed with a short appendage at the end ; the club-joints covered with a few long ciliae, each longer than a joint. *Thorax* short, smooth and shining ; parapsidal furrows well marked, straight ; scutellum as long as broad, rounded behind ; propodeon very short, transverse, with a yellow triangular area in the middle. Wings not very broad, rounded at apex, with long marginal ciliae ; discal ciliae very short and not numerous, arranged in regular lines ; marginal vein a little longer than the submarginal, somewhat thickened at the base, with a short brown line below ; stigmal vein as long as one-third of the marginal vein, with a thick, shortly petiolated knob. Postmarginal vein absent. Hind wings narrow, discal ciliae on lower margin as long as the discal ciliae of the fore wings and a little longer than the breadth of the hind wing ; discal ciliae in two rows. Legs narrow, relatively short. *Abdomen* longer than head and thorax together, strongly compressed from the sides, very narrow when seen from above, and pointed behind.

♂. Similar to the female, smaller; antennae shorter, the funicle and club broad and compressed; the two funicle joints large, broader than the pedicel, the 1st little broader than long, the 2nd transverse; the three club joints short, as broad as the funicle, transverse, the 3rd joint smaller, triangular, situated in an excavation of the 2nd, the sides of which are pointed; all joints with long thick hairs. Abdomen not longer than the thorax, also slightly compressed from the sides.

Length: ♀, 0·7–0·8 mm.; ♂, 0·6 mm.

MALAY PENINSULA: Johore, 12 ♀♀, 2 ♂♂, i.1929 (*G. H. Corbett*).

Host. Egg-mass, believed to be that of a Membracid.

Type deposited in the British Museum.

This species seems specially related to *A. acuminata*, Ashm., of U.S.A. (see Girault, Trans. Amer. Ent. Soc., xxxvii, 1911, p. 77), but that species has the antennae shorter and the abdomen broader and longer, and is quite different in coloration. It is also related, on account of the elongate club of the antennae, to *Ittys ceresarum*, Ashm. (Girault, *loc. cit.*, p. 25), but the genus *Ittys*, Gir., has the funicle joints longer than broad, the abdomen generally shorter and broader, and more ciliated wings. This Asiatic species differs from the other species of *Abbella* in the compressed abdomen of the female and the flattened antennal flagellum of the male.

Haeckeliana brontispae, sp. n. (fig. 5, *d*, *e*).

♀♂. Body dark brown, almost black, head reddish brown. Antennae brown, the end of the club paler. Legs brown, a small ring near the base of the hind tibiae, the tip of all tibiae and the tarsi yellowish. Wings infuscate to a little beyond the stigmal vein, the terminal third of the wing hyaline; a faint rounded hyaline spot below the middle of the marginal vein.

♀. *Head* as broad as the thorax, shagreened; ocelli forming a low triangle, the posterior ocelli as far from each other as from the eye-margin; eyes rounded, covered with short straight hairs. Seen from in front the head is a little broader than long. Mandibles with 4 teeth, two large, acuminate, and two smaller, below. Antennae inserted a little below the middle of the face, at the base of a short rounded antennal furrow; they are not longer than the face and much thickened; scape elongate, but shorter than the antennal furrow, about 4 times as long as broad; pedicel very thick, shorter than the scape, more or less oval in outline, covered with fine transverse carinae; one small annellus (not easily seen) is generally hidden, with the tip of the pedicel under the base of the club; the club thick and irregularly rounded, not much longer and broader than the pedicel; the joints strongly united and irregular, not easily separated, but after comparing different antennae, there seem to be 4 joints, as drawn (fig. 5, *d*); a 5th joint is thin and elongate like a spur, as long as the rest of the club; all joints of the club bear some long, strong ciliae. *Thorax* short, rounded; pronotum very short, visible only at the sides; mesonotum broader than long, with complete parapsidal furrows; scutellum also broader than long, rounded behind; propodeon almost as long in the middle as the scutellum, with lateral furrows; spiracles small, rounded. Wings long and broadly rounded; marginal vein longer than the submarginal, thickened at the base and there with two long setae, not coloured in the middle, and again thickened (but less so) on its terminal half; there with a row of very thick hairs; stigmal vein long and thin, as long as half the marginal, the knob small; postmarginal vein not developed. Marginal ciliae short; discal ciliae arranged in regular rows; there are about 10 main rows, between which are some small irregular lines; the oblique line below the stigmal vein is formed of about 8–10 ciliae. Hind wings rather broad, the marginal ciliae as long as the breadth of the wing, the discal ciliae forming 3 regular lines. Legs short, strong, posterior femora a little thickened. *Abdomen* short, sessile, almost as broad as and a little longer than the thorax, with parallel margins until the 4th segment, then pointed behind. Ovipositor slightly protruding.

♂. Very similar, but smaller; the antennae have the same general form, but the club is smaller, not much longer than the pedicel, and the last joint is not thin and elongate, but broader and shorter; triangular. In the wing the infuscation does not extend beyond the stigmal vein on the upper part, but reaches the same point on the lower margin.

Length: ♀, 0·6–0·8 mm.; ♂, 0·5 mm.

JAVA: 10 ♀♀, 1 ♂, 1930. SOUTH CELEBES, 14 ♀♀, 1930 (*R. Awibowo*). All in Canada balsam.

The specimens from Celebes are on the average a little larger than the Javanese specimens.

Hosts. Eggs of *Brontispa longissima*, Gestro (Java), and of *B. froggatti* v. *selebensis*, Gestro (Celebes).

Type deposited in the British Museum.

This species is best placed provisionally in the genus *Haeckeliana*, Girault, but it may prove to belong to a new genus. In the key to the genera of TRICHOGRAMMATIDAE given by Girault (Bull. Wisconsin Nat. Hist. Soc., xi, 1913, p. 150, and xii, 1914, p. 55) it runs directly, in the tribe OPHIONEURINI, to *Haeckeliana*. The original description of this genus, of which only two species from Australia are known, is as follows (Mem. Queensl. Mus., i, 1912, p. 97):—

" A genus similar in all respects to *Ufens*, Girault, but bearing no funicle in the antennae, the club larger, fusiform-acuminate, that is broad at base and tapering to a point at apex, 5-jointed, the proximal joints short and transverse, the apical two joints long and narrow, the last joint longest and narrowest, a third longer than the preceding joint; also the club bears rather long, thick, spinelike setae, somewhat like the single thickened seta from the apex of the club in *Oligosita* but here much longer and acuminate. Scape and pedicel normal. Mandibles with at least three teeth. Marginal and stigmal veins short, the latter slightly shorter than the former. Cephalic tibial spur present, minute, straight and acute. Posterior wings with their caudal marginal cilia longer than the width of the blade. Ovipositor not long, inserted nearer middle than to base, non-exserted. Otherwise as in *Ufens*."

It will be seen by the above that the general form of the antennae is different, but that the Oriental species has in common with the Australian species the transverse proximal joints of the club, the elongate narrow last joint and the long spinelike setae. The anterior wings are also broad and rounded as in the genus *Ufens*, Girault.

Both Australian species were described by Girault from single specimens captured on windows.

Family MYMARIDAE.

Polynema elisabethae, sp. n. (fig. 6, *a*, *b*).

♀. General colour clear yellow. Head with a transverse brown stripe on the frons between antennae and ocelli; eyes reddish brown. Antennae yellow, the last joint brown, the base of each joint also slightly brownish. Legs entirely clear yellow.

Head large, shagreened, rounded behind the eyes. Posterior ocelli nearer to the eye-margin than to each other, but at the same distance from the eye-margin as from the anterior ocellus. Antennae very thin, elongate, with 9 joints; scape short, reaching a little beyond the front ocellus, slightly enlarged; pedicel narrower but about as long as the scape, 3 times as long as broad; the first three funicle joints very thin, straight and long, the 1st longer than the pedicel, the 2nd about twice as long as the 1st, the 3rd little shorter than the 2nd, the 4th shorter, broadening at apex, the 5th and 6th a little broader, oval, elongate; club entire, broader than

and about as long as the two preceding joints together; the length of the joints in 1/1000 mm. is: 62, 54, 92, 175, 167, 121, 92, 83, 183. *Thorax* long, narrower than the head; pronotum elongate, narrowed in front; scutellum longer than broad; propodeon short, without carinae. Wings long, narrow; discal ciliae numerous and short; marginal ciliae a little longer than the greatest breadth of the wing; the general form of the wing as in fig. 6, *b*, very narrow at base, with the lower margin enlarged beyond the marginal vein, the wing then progressively broadening to apex, the apex itself somewhat pointed; marginal vein short, a little broader than long, light-coloured and not easily seen. Hind wings very thin, filiform, elongate with long marginal ciliae along the lower margin. Legs very narrow and elongate, longer

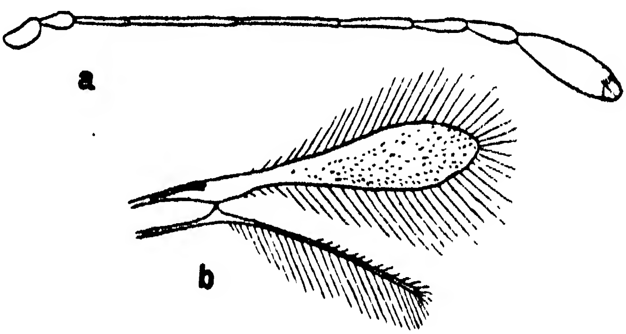

Fig. 6. *Polynema elisabethae*, sp. n.: *a*, antenna of ♀; *b*, fore and hind wings.

than the body; tarsi with 4 joints. *Abdomen* with the petiole longer than the hind coxae, almost as long as the rest of the abdomen; the other segments together shorter than the thorax, pointed behind. Ovipositor inserted below the 2nd segment, not protruding.

Length: 1 mm.

JAVA: Buitenzorg, 1 ♀, vii.1925 (*R. Menzel*).

Host. Eggs of *Euproctis flexuosa*, Snell.

Type, on a slide, deposited in the British Museum.

This species is characterised by its yellow coloration (the species of *Polynema* being generally dark), by the form of the wings, and by the length and thinness of the funicle joints.

ON THE ANATOMY OF THE LARVA OF *LACCIFER LACCA*, KERR (HEM. COCCIDAE).*

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Introduction.

In order to follow the changes appertaining to the post-embryonic development of the larva of the Indian lac-insect of the genus *Laccifer* a knowledge of its external

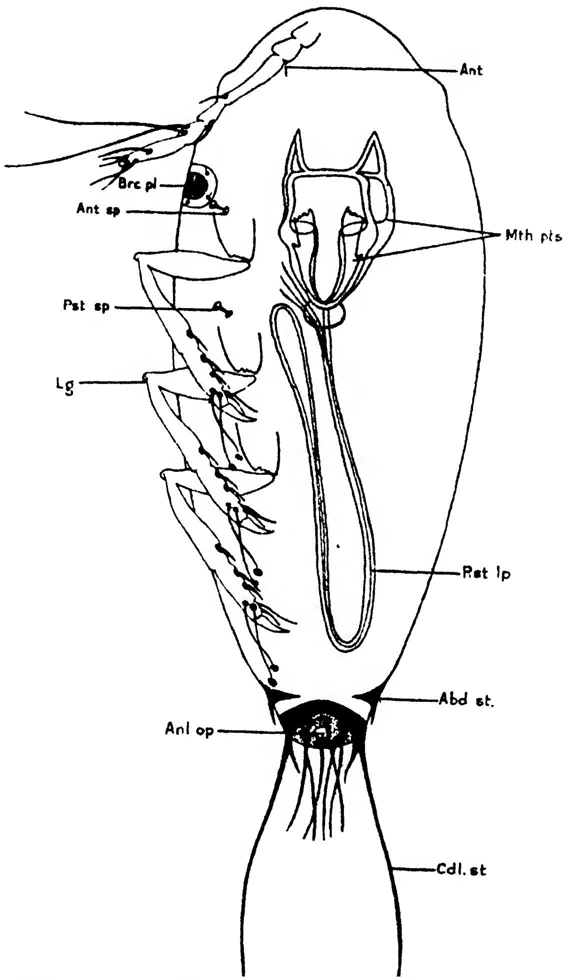

Fig. 1. Ventral view of larva : cleared in KOH and mounted in balsam—camera lucida sketch, × 150.

and internal anatomy was a desideratum. A study of its external and internal anatomy was, therefore, undertaken in order to obtain a knowledge of its organography, and the following account is based on the results of such a study.

* This paper formed part of a thesis approved for the degree of Doctor of Science in the Lucknow University.

The work was done by me at the Zoological Laboratory of the Lucknow University under the supervision of Professor K. N. Bahl, D.Ph., D.Sc., during my tenure of the United Provinces Government Research Scholarship. I am indebted to Professor Bahl not only for valuable suggestions, but also for going through and correcting the manuscript of this paper.

Historical and Critical.

The larvae of the Indian lac-insect seem to have been known to us since time immemorial, and the technical vernacular name *lakh* for the resin produced by the insect is said to have been derived from the Sanskrit word " laksh," meaning a hundred million, which owes its origin to the fact that these young ones swarm out in millions.

A description of the external characters of the larva of the lac-insect of the genus *Laccifer* (*Tachardia*) is available to us from the excellent accounts of Imms[2], Stebbing[15], and Lefroy[4], but a knowledge of its internal anatomy is not known to have been worked out hitherto.

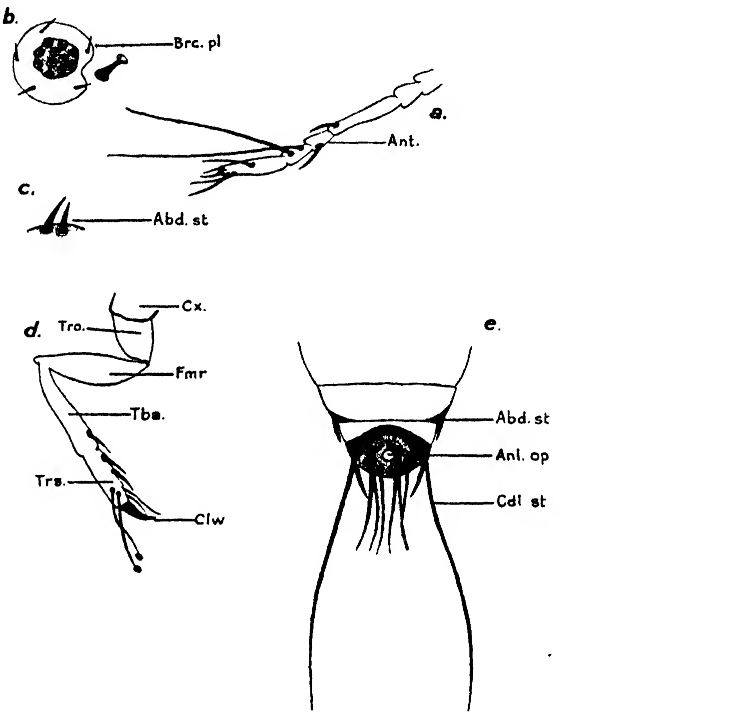

Fig. 2. External characters of the larva, KOH preparations : *a*, antenna, × 150 ; *b*, brachial plate and spiracle, × 324 ; *c*, setae borne by the penultimate abdominal segment, × 150 ; *d*, leg, and *e*, pygidium, × 150.

Imms' and Stebbing's accounts of the external characters of the larva are fairly accurate and satisfactory. There are, however, certain errors of minute detail which struck me during the comparison of their accounts with my microscopic preparations of the whole mounts of the larva and its various parts. The brachial plate possesses 10–12 dimples instead of five as recorded by Imms and, in addition to these, has a few pores on the collar of its crater. The brachia are sessile, and hence the anterior spiracles lie close to the brachial plates (fig. 1). Imms' account contains no reference to the setae borne on either side by segment 8/9; the cuticle at the sides of this segment is thickened to form a plate in which are embedded two stout setae (fig. 2).

The cuticular covering of the larva bears numerous spines, which are constant in their position and number, to which no reference has been made by previous authors. There are six slender spines between the eyes, six similar ones on the margins of the thorax, and one spine on either side of each of the abdominal segments. In addition to these, the abdominal segments possess two rows of spines on the dorsum and the venter.

Imms and Stebbing were certainly wrong in their observations upon the mode of emergence of the larvae. Since this point has more elaborately been dealt with by me in a previous paper[11], it seems unnecessary to repeat it here *in extenso*. Suffice it to say that the larvae do not issue out of the back of their mothers by puncturing a hole through it (*vide* Stebbing), nor through the anterior spiracles as suggested by Imms, but one by one out of the female genital opening on the anal tubercle, quite in the normal manner.

Stebbing[15] tried to establish secondary sexual differences in the larvae by means of comparative illustrations of the antennae of the so-called male and female larvae. During the course of my studies on this insect, I have made scores of balsam preparations of whole larvae showing their pygidia and antennae, but I have not been able to detect any such differences and am therefore not able to corroborate Stebbing's statement.

External Characters.

The larva is a minute creature of extremely active habits. Its body is ovate in outline with the dorsal surface convex, being broader at the anterior extremity, especially in the region of the thorax, and tapering posteriorly. It measures 0·6 mm. in length, and 0·2 mm. across the thoracic region ; individual specimens will be found to vary within narrow limits of these measurements. The body is divided into a head, thorax and abdomen, but there is no pronounced demarcation between these regions. The head carries a pair of antennae, a pair of ocellanae, and ventrally the mouth-parts. The antennae (fig. 2, *a*) are composed of six segments including the basal one ; of these, the two basal joints are small and rounded, the third joint is longer than the rest, the fourth and fifth joints are almost subequal, and the terminal segment is nearly as long as the preceding two. Setae are borne by all the segments of the antennae except the two basal ones, those of the fifth segment being the longest, and the terminal joint is provided with several short stout setae (fig. 2, *a*). The head carries a pair of ocellanae external to the insertion of the antennae. The ocellanae (fig. 3) look like circular spots only slightly elevated above the level of the head and are located marginally on it. The mouth-parts are situated on the underside of the head and have been carried away far behind, being located only a little in front of the first pair of legs (fig. 1). They are built essentially on the same ground-plan as those of the female, but the rostrum is greatly elongated, inasmuch as its U-shaped loop occupies a great deal of the abdominal cavity of the insect, and consequently the crumena extends up to the end of the fifth or sixth abdominal segment (fig. 1). The prothorax is the largest of three segments composing the thorax. On the ventral side, the thorax carries two pairs of spiracular openings, the anterior one (fig. 1) being situated in front of the first pair of legs, and its position indicated by a sieve-like brachial plate surmounting a cup-like depression. The posterior pair of spiracular openings is situated between the first and the second pairs of legs (fig. 1), and is essentially of the same type as the anterior pair, but lacks the sieve-like brachial plate.

The legs (fig. 2, *d*) consist of two basal joints, the coxa and the trochanter, the spindle-shaped femur, and the tibia, bearing apically the tarsus which ends in a claw ; the tarsus bears two long empodial hairs. The nature of these component parts is best indicated by the accompanying figures, and hence a detailed description seems superfluous (figs. 1, 2, *d*).

The abdomen consists of 8–9 segments of which the last few seem to fit in telescopically. The anal ring at the abdominal extremity carries a pair of caudal setae (fig. 2, *e*) which are approximately as long as the entire body. The anal opening is situated in the centre of the anal ring and is surrounded by a group of six anacerores (fig. 3) and six shorter setae. Reference has already been made elsewhere to the presence and distribution of certain spines on the body of the larva.

The Lac Glands.

The integument of the larva is made up of the external cuticle under which lies the hypodermis, many of whose cells are modified into lac glands. Structurally the lac glands of the larva correspond to the diffuse type of lac glands of the female lac-insect, which are characterised by the possession of very delicate ducts. In the larva there is no indication of the specialisation of the lac glands into two distinct types as is seen to be the case in the female lac-insect[13], nor even the segregation of the flask-shaped glands to particular areas. As a matter of fact, flask-shaped glands are absent at this stage. The lac glands of the larva are indifferently and densely distributed under the whole of the integument (fig. 3). In a surface view of a whole mount of the larva the integument appears studded with these glandular cells. Each gland is a unicellular structure with a prominent nucleus, an enlarged fundus, and a delicate duct opening on the surface of the body. An account of the mode of secretion of the resinous cell by the larva from the time of its settlement on the succulent twigs of the host plant to the time of its complete encasement in a resinous cell, and of its further growth during life, has been given by me in another paper[12].

The Salivary Glands.

The gut of the larva is built on the same ground-plan as that of the male and female lac-insects described by me elsewhere[13].

The salivary glands, or the "Speicheldruse" of the German authors and the "storage glands" of others, have been identified, as such, only in the case of *Dorthezia* by Dufour (quoted by Mark) and in *Lecanium* by Mark himself[8]; whilst a host of workers* on Coccidae have either inadequately described them or misunderstood their real nature and, consequently, regarded them as parts of the "Unterschlund-ganglion." Since the historical growth of our knowledge of this structure has adequately been dealt with by Mark, only a cursory reference to the nature of the errors of the earlier authors is made here. So far as my information goes, Leydig[5] was the first to detect these organs in *Lecanium*, but he mistook them for parts of the nervous system and described them as such. He was correct in calling them "traubegelappt," but having misunderstood their morphological value, he sought to offer an explanation for their assumption of the form of "a bunch of grapes," and succeeded in doing so with great skill; but a moment's reflection brings home the fact that although by playing with words Leydig sought to establish the nervous nature of the structure under discussion, yet he knew the weakness of his arguments and was, probably, as doubtful of his assumption as we are to-day. Furthermore, Leydig's account has to be accepted with great caution, for his investigations have reference to two different genera; for this reason it is always difficult to make out whether he refers to the storage glands of *Lecanium* or *Aspidiotus*. Not content with this, Leydig further sought to establish a homology between these so-called parts of the nervous system and the "Primitivefasern des Nervus olfactorius und der Remak'schen Fasern oder an den Axencylindern der Wirbelthiere."

Leydig's views appear to have commended themselves to Lubbock[7], who also described similar structures in *Coccus hesperidum* in a similar manner, and treated

* Burmeister, Kunckel, Leydig, Targioni-Tozzetti and Lubbock.

them in that section of his account which dealt with the nervous system. This is additional evidence of the fact that he regarded them to be of a nervous character. Apart from this, he also endeavoured to homologise them with the "Zellenkorpern" described by Leuckart in the larvae of *Melophagus*.

Targioni-Tozzetti[17], who professed to have studied these structures in greater detail, also regarded them as parts of the nervous system and called them "cellule nervose." He further noticed a canal which he described as a thin tube with sharply defined and resisting walls and branched at its proximal end, these branches ultimately ramifying to the individual "lappen." Although Targioni-Tozzetti described these in the manner indicated above yet one of his statements tends to throw his observations into doubt. "Particolarità non descritta da alcuno è un tubo molto sottile ma a pareti altretanto ben definite e resistenti, il quale, unico all'origine, poi biforcato con un ramo nella lamina lobulata di ciascun lato, la percorre tutta nell'asse, e giunto

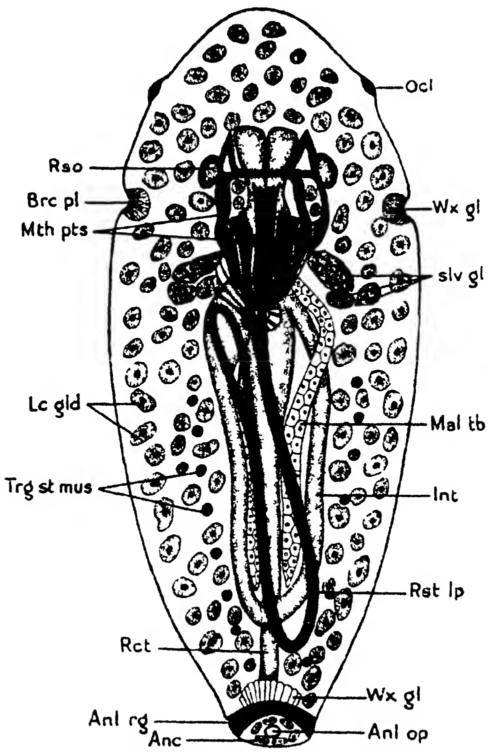

Fig 3. A complete larva showing disposition of internal organs. camera-lucida drawing of a mount in balsam, × 150

dove questa termina ingrossata, qui chiaramente si divide e si subdivide. Ignoriamo la natura e l'ufficio vero di quest'organo, che ha, per la grossezza e la resistenza sua, le qualità di una trachea, come si hanno nei *Diaspis*, ma non ne ha il colore, e non si mostra dipendente da alcuno dei tronchi principali, coi quali le trachee medesime si diffondono pel corpo di questi animali." Mark says, "Wir kennen nicht die Natur und die wirkliche Bedeutung dieses Organs, welches nach Grosse und Festigkeit die Eigenschaften von Tracheen bei *Diaspis* hat; aber es hat nicht die Farbe der Tracheen und steht in keinem Zusammenhange mit den Hauptasten' von welchen sammtliche Tracheen dieser Thiere ihren Ursprung nehmen." These contradictory remarks of the author regarding the same structure affect the value of his views as to the true

nature of these parts. As the subsequent work of List[6] showed, the thin tubes referred to by Targioni-Tozzetti were nothing but the ducts of the salivary glands, and the ramifications which baffled him were the ductules of the component spherules of the gland Mark, after studying five different genera of COCCIDAE, arrived at the conclusion that these structures were nothing else but "Speicheldrusen." The fact that in Hemiptera these organs exhibit a wide range of form and position is probably the

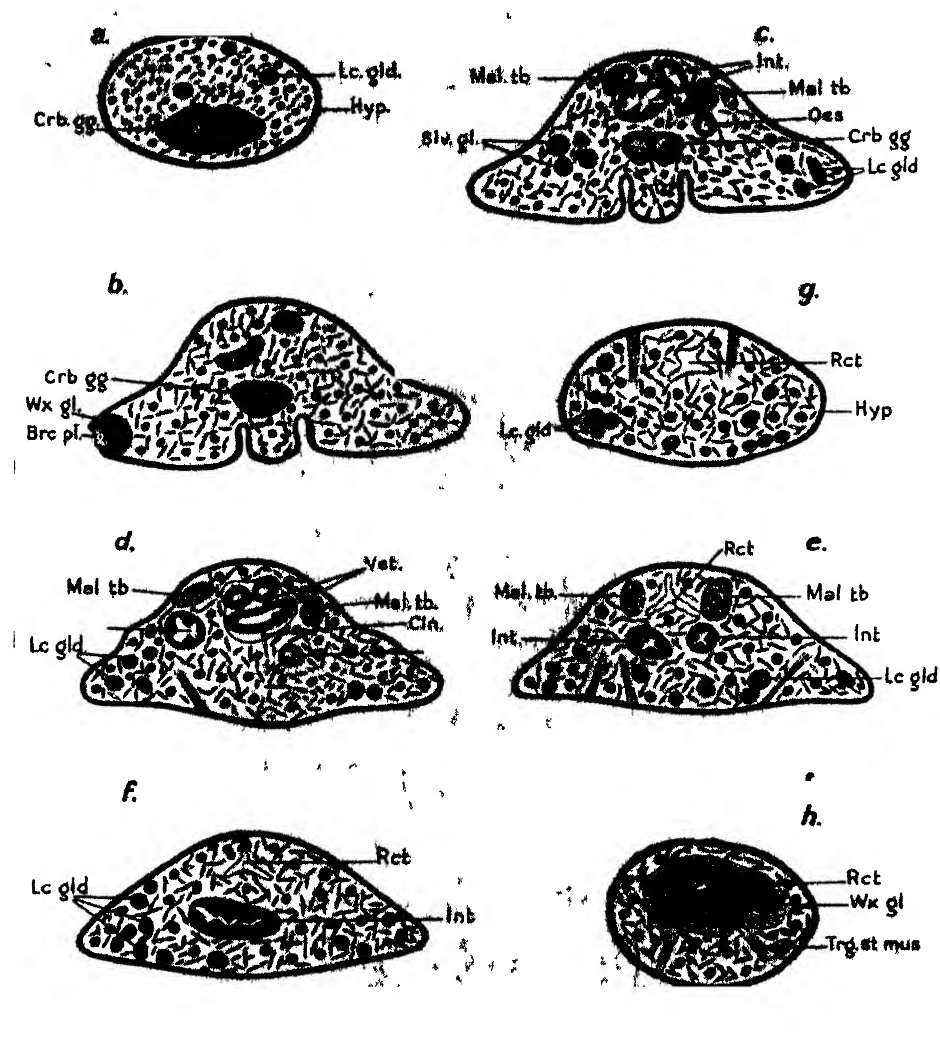

Fig 4 Transverse sections of the larva through different regions of the body camera-lucida outlines × 155

reason for so much confusion and the consequent erroneous and varied interpretations of them by different authors.

I agree with Mark[8] that the structures under discussion are not parts of the nervous system, an error that was due to the close proximity of these organs to the

supraoesophageal ganglion or the brain. More recently these structures have been elaborately dealt with by List, and for a fuller treatment reference may be made to his paper[6].

The salivary glands of the lac-insect larvae are comparable to the corresponding organs of *Physokermes insignicola*[10] and *Gossyparia ulmi*[3]. On either side of the mouth-parts there is a bunch of spherical lobes resembling a "compact bunch of grapes," the salivary duct issuing out of these corresponding to the stalk in the nature of its relationship with the individual lobes. Each of these lobes is a multicellular, granular vesicle with prominent nuclei (fig. 4, *c*). These glands lie symmetrically in the immediate neighbourhood of the mouth-parts, closely applied to the sides of the "Unterschlundganglion" which overlies the chitinous framework of the mouth-parts, and so disposed as to embrace the sides of the ganglion to an appreciable extent. The ducts of the two sides issue forwards and downwards and soon converge to meet in the middle line to empty themselves into the "Ausfuhrungsgang," the unpaired emptying passage formed at the base of the framework of the mouth by the apposition of the rostral setae.

The Nervous System.

The nervous system (fig. 5) of the larva consists of the brain and the ventral nerve-cord. The brain is a compact structure lying in the region of the head partly overlying the chitinised framework of the mouth (fig. 3). The cortical part of the

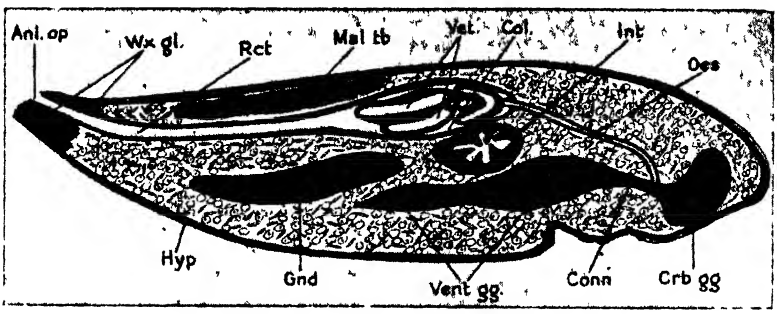

Fig 5 Sagittal section of an advanced larva, reconstructed from two sections, camera-lucida sketch, × 150.

cerebral ganglion is numerously studded with deeply staining nuclei, while the medulla seems to be of an even composition and is sharply differentiated from the former on account of the absence of such nuclei (fig. 5). The contrast is, therefore, sharply marked. In longitudinal sections the cerebral ganglion or the brain appears kidney-shaped and, though theoretically dorsal to the oesophagus, lies in front of the mouth-parts, which have shifted backwards on the venter to a position approximated to the first pair of limbs. The cerebral ganglion is connected with the ventral nerve ganglion by means of a pair of connectives which tightly embrace the oesophagus between them. The connectives lie just above the chitinous framework of the mouth. The ventral nerve cord is represented by a massive compound ganglion (fig. 5) formed by the fusion of all the thoracic and abdominal ganglia. Structurally this ganglion has the same histological composition as the cerebral ganglion described above and, in sections, shows itself to be composed of 6–7 ganglia fused together. Three out of these probably belong to the oral region, three to the thoracic segments, and the last one to the first abdominal segment. It is rather interesting to note this departure from the normal type of the ventral nerve cord met with in other insects; and since only one abdominal ganglion is discernible at the tail end of this massive ganglion, it is puzzling to account

for the absence of the remaining ganglia belonging to the rest of the abdominal segments, since the abdomen of this larva consists of 8 to 9 segments. Shinji[16] remarks that " In Coccids, as in other insects, there is originally one ganglion in each of the body segments, making three in the brain, three in the oral region, three in the thorax and ten in the abdomen or nineteen in all. Shortly after the union of the stomadeum invagination with the entoderm or the midgut, all the abdominal ganglia, except the first, disappear, leaving only the longitudinal nerve fibres behind. These slender nerve fibres, it may be added, run out from the posterior margin of the only surviving abdominal ganglia and innervate the abdominal organs, such, for example, as the ovaries, midgut, etc."

The Wax-glands.

The wax-glands of the larva of the lac insect are found in association with the brachial plates and also round the anal opening (fig. 3). On examining the brachial plates in surface view, the wax-glands are seen forming a circular disc underneath it. In an examination of the living larva, nothing will be found more striking than the white wax filaments protruding out of these plates and similar filaments from the caudal end of the larva. In sections the wax-glands stand out more prominently than other parts on account of their deeply staining property. The facts that wax threads issue out of the distal ends of these glands and that they have an intensive affinity for dyes betray their glandular character, and the solvent action of ether and chloroform on the threads confirms the waxy nature of the fibres formed by them. Under the brachial plate and around the rectal tube (figs. 3, 4, *h*) these wax-glands form a compact mass.

The wax-glands are of a pluricellular nature and open on the surface through the dimples on the brachial plate and the cerores on the anal plate. They are so compactly bundled together that individual gland-cells cannot be made out in sections 6μ thick, but in teased or macerated preparations the following facts concerning them can be observed. The neck ends of the glands are somewhat free, limitations of the fundi being not clearly discernible on account of their plural nature. The presence of more than one nucleus in the fundus region suggests their pluricellular nature.

Berlese (quoted by Childs), in describing the wax-glands of the DIASPIDINAE, differentiated in them the " ghiandola sericipara " and the " ghiandola ganogene," and maintained that while the " ghiandola sericipara " secreted the wax, the ganogene cells furnished a substance which was used for coating the exterior of the threads of wax. He had, however, no circumstantial or direct evidence to support this view. These structures were figured by Childs[1], but he did not arrive at any definite conclusion regarding their structure or function. Later Matheson[9] made a study of the cerores of *Pseudococcus citri* and recognised five distinct types of glands. My preparations do not agree structurally with the account published by him, and hence no comparisons are made here. Matheson appears to have no definite ideas concerning the form and function of wax-glands in *Pseudococcus citri*, because he says : " What the particular function may be I have no means of determining, and I have been unable to determine the exact type of external opening and I am still in doubt whether it is an actual gland or the beginning of it." It seems to me that these wax-glands of the larva resemble structurally the second type of ventral gland of *Saissetia oleae**. My preparations bear a strong resemblance to Marshall's figures 17 and 19.

The Tracheal System.

The complex ramification of the tracheae within the body, at various levels, presented considerable difficulty in the study of the tracheal system of the larva.

* Marshall, W. S. The Hypodermal Glands of the Black Scale, *Saissetia oleae* Bernard. Part 2.—Trans. Wisc. Acad. Sc. Arts & Letters, xxv, 1930, p. 254.

It was only after numerous attempts that the following facts concerning it were gathered. The course of the principal tracheal trunks has been reconstructed from the study of a large number of preparations, and it is believed that the accompanying diagram represents a very close approach to the natural disposition of the tracheal ramifications.

As has already been stated elsewhere, there are two pairs of spiracular openings on the venter. Three tracheal trunks seem to arise from each of the anterior spiracles. The first of these gives off an antennary branch (*Ant. br.*) to the antenna, an ocellar (*Ocl. br.*) branch to the eye, a podial (*Pd. br.*) ramus to the first leg, and an extra one (*Ext. br.*) which arises somewhat cephalad of the podial one but pursues a backward course medianly through the thorax. The second tracheal trunk gives off a stout commissure (*Ant. com.*) lying transversely across the thorax and connecting

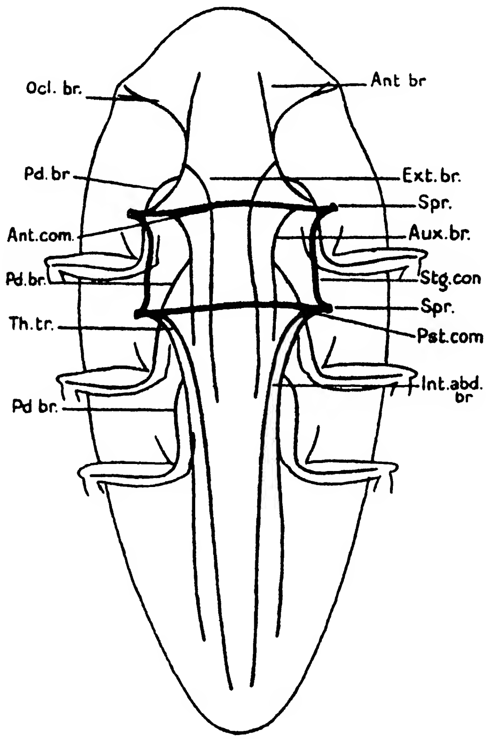

Fig. 6. The tracheal system of the larva, × 150.

the anterior spiracles of the right and left sides. Besides this, it also gives off a branch (*Aux. br.*) which pursues a backward course and lies external to the similarly disposed branch of the first trunk. From the second trunk also comes off a branch to the middle leg, but it is not quite clear whether this is an offshoot from the preceding branch or an independent one from the trunk. The third tracheal trunk is a stout one and runs backwards to join the posterior spiracular opening of its side (*Stg. con.*).

Three main trunks also arise from each of the posterior spiracles for the tracheation of the abdominal parts of the body. The first trunk appears to have fused with the stigmatal connective referred to above and its identity is, therefore, obscure. The second trunk lies transversely across the abdomen and joins the posterior spiracle of the other side to form an abdominal commissure (*Pst. com.*). It also gives off

an offshoot (*Int. abd. br.*) running backwards close to the median line. The third trunk sends a branch to the hind leg and then pursues a course parallel to the internal abdominal branch.

Besides these main trunks and their important branches herein described, numerous minor tracheolar branches are recognisable, but it is not easy to evaluate them on account of the difficulty of tracing them to their source of origin. The tracheal branches going to the antennae, limbs, and the two commissures and connectives, are more prominent than others. The completeness of tracheation of the body of the larva is noteworthy inasmuch as it tends to bring every part of its body in relation with the tracheolar rami. The great activity of the larva is undoubtedly correlated with this fact.

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Lettering of the Illustrations.

Abd. st. ... Abdominal seta.
Anc. ... Anacerore.
Anl. op. ... Anal opening.
Anl. rg. ... Anal ring.
Ant. ... Antenna.
Ant. br. ... Antennary branch
Ant. com. ... Anterior commissure.
Brc. pl. ... Brachial plate.
Cdl. st. ... Caudal seta.
Cln. ... Colon.
Clw. ... Claw.
Conn. ... Connective.
Crb. gg. ... Cerebral ganglion.
Cx. ... Coxa.
Ext. br. ... Extra branch.
Fmr. ... Femur.
Gnd. ... Gonad.
Hyp. ... Hypodermis.
Int. ... Intestine.
Int. abd. br. Internal abdominal branch.
Lc. gld. ... Lac gland.
Mal. tb. ... Malpighian tube.
Mth. pts. ... Mouth parts.
Ocl. ... Ocellena.
Ocl. br. ... Ocellar branch.
Oes. ... Oesophagus.
Pd. br. ... Podial branch.
Pst. com. ... Posterior commissure.
Rct. ... Rectum.
Rso. ... Retort-shaped organ.
Rst. lp. ... Rostral loop.
Slv. gld. ... Salivary gland.
Spr. ... Spiracle.
Stg. con. ... Stigmatal connective.
Tba. ... Tibia.
Th. tr. ... Third trunk.
Trg. st. mus. Tergo-sternal muscle.
Tro. ... Trochanter.
Trs. ... Tarsus.
Vent. gg. ... Ventral nerve ganglion.
Vet. ... Ventriculus.
Wx. gld. ... Wax gland.

METHODS OF PHOTOGRAPHING LIVING INSECTS.

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(Plates VIII–XVII.)

When teaching Entomology under University conditions, it is difficult to avoid giving students the impression that the principal, and perhaps the only, function of an entomologist is the examination of insect-corpses in great detail. Some years ago, when appointed lecturer on Entomology at the University of Sydney, I was faced with the problem of how to deal with this difficulty. Eventually I came to the conclusion that the only satisfactory solution of the problem was to obtain photographs of living insects with which to illustrate lectures, for it is almost impossible to arrange for students actually to handle more than a very small number of living insects. As the number of suitable photographs which have been published is small and quite inadequate for lecturing purposes, I found it necessary to take the photographs myself.

It soon became evident that the photography of insects presents special and serious difficulties as compared with normal photography. This is due principally to the fact that insects are small and usually very active. It is necessary that photographs should at least approximate to the natural size of insects, and for this a long bellows extension is required. Also, when objects are photographed at a size even approximating to natural size, the depth of focus becomes almost negligible, being only a small fraction of an inch at normal stops. It is desirable, therefore, that very small stops should be used in order to obtain a reasonable depth of focus. Long bellows extension and small stops both necessitate the use of longer times of exposure than would otherwise be necessary.

On the other hand, the rapid movements of insects, combined with the fact that insects must necessarily be close to the camera when photographed, calls for the use of very rapid exposures. That is to say, in order to cope with movement very short exposures must be given, while in order to obtain a properly exposed plate and a reasonable depth of focus long exposures are necessary. To overcome this difficulty in a satisfactory way one must either use a plate which is many times faster than the fastest at present on the market, or use some source of light which is much brighter than daylight. If neither of these alternatives is practicable, one may compromise by using large stops and sacrificing depth of focus.

When photographing insects in the field, a further difficulty arises owing to their rapid movements. It is usually impossible to focus an insect on the ground-glass of a stand-camera and then to substitute a plate and make an exposure, for by this time it is practically certain that the insect will have moved out of focus. Consequently it is necessary to use some kind of hand-camera with which the insect can be followed in all its movements. It is also necessary that there should be some means of focussing such a camera with accuracy right up to the moment when the exposure is made; for the depth of focus is so shallow that if the camera is only a fraction of an inch too near, or too far away from, the insect, the resulting photograph is worthless.

The methods described in this paper have been evolved with the object of dealing with the difficulties just mentioned. Though I have now used these methods for several years, I must point out that they have not yet completely emerged from the experimental stage, and further improvements will almost certainly be possible. However, these methods in their present state of development should be of use to many entomologists. The methods are so simple and seem so obvious that it is highly probable that similar methods have been used before. However, whether this is so or not, it is certain that the methods are not generally known to entomologists.

Photographing Insects in the Field by Daylight.

A. *Outline of Possible Methods.*

Certain insects, such as those which sit motionless on tree-trunks, may be photographed satisfactorily by means of an ordinary stand-camera, but if such a camera is used, there is a severe restriction of the types of objects which may be photographed. The entomologist, however, wishes not merely to take photographs of insects, but to take photographs of those insects in which he is interested, showing these doing the things he wishes to illustrate.

Moving insects may be photographed by means of a reflex camera, provided that

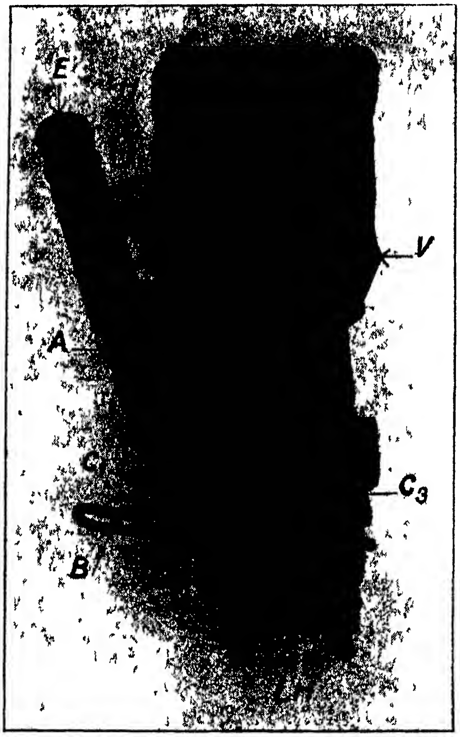


Fig 1 The field camera with focussing attachment . A, focussing attachment ; B, bracket with cam-slot , C_1, C_2, C_3, clamping screws , E, eyepiece, and L, front lens of focussing attachment , H, hinge , LH, lens hood , V, velvet cover.

it has a sufficiently long bellows extension. With such a camera very good results could often be obtained, but to the entomologist there are serious limitations to the use of a reflex camera. In the first place the reflex camera can only be used satisfactorily when held at waist-level, with the axis of the camera horizontal. Under field conditions it is found that such a position is usually unsuitable when photographing insects. Perhaps a more serious limitation to the use of a reflex camera is that caused by its weight and cumbersome nature. What the entomologist requires is a small folding camera which he can carry wherever he goes in the field and use whenever he wishes to record anything he sees. A reflex camera is much too cumbersome for this.

The only reason why an ordinary folding pocket camera, fitted with a double extension, cannot be used for photographing insects in the field is that there is no

mechanism for focussing accurately on the object right up to the moment the shutter is released. The apparatus about to be described is designed to render such focussing possible.

The focussing attachment is shown in fig. 1. It consists of a lens, having exactly the same focal length as the camera lens, which is mounted in the small end of a telescope tube. This end of the telescope tube is attached to the lens-carrier of the camera, while the large end of the telescope tube is attached to the body of the camera.

Consequently, as the bellows of the camera is racked out, the telescope tube is lengthened to the same extent. As the lenses of the focussing attachment and the camera have the same focal length and are attached to one another, whenever an image is in focus on the plate in the camera another image, formed by the lens of the focussing attachment, is in focus at a position in the large end of the telescope tube which is equivalent to the position of the plate in the camera. A telescope eyepiece is mounted in the large end of the telescope tube in such a way that it is in focus on the position just mentioned. It is evident, therefore, that whenever an object is in focus in the focussing attachment it is also in focus in the camera.

The above gives the general principle of the construction of the apparatus. The method of using it is as follows. No attempt is made to bring the object into focus by racking the bellows of the camera in and out. By means of graduations on the rack of the camera and on the attachment, the camera is set up to take the object at some particular size, say three-quarters of natural size. The shutter is set, the stop is adjusted and the cover is withdrawn from the darkslide and everything is then ready for taking a photograph. The apparatus is then pointed at the insect to be photographed and is moved bodily towards or away from it till the image can be seen clearly in the eyepiece of the attachment, when an exposure can be made. The apparatus is shown in use in Plate VIII.

It will be seen that in principle both the construction and the use of the focussing attachment is very simple. There are, however, many important details which have so far been omitted for the sake of simplicity.

B. *Details of the Focussing Attachment.*

The lens I have used in the focussing attachment is a simple plano-convex one, which naturally has many optical defects. Most noticeable amongst these are chromatic and spherical aberration. Actually this does not matter much, for it is merely necessary to be able to judge when the image is in focus in the attachment, which is quite possible even with such a crude lens. No doubt a more perfect lens would be preferable, but I do not advocate the use of a duplicate of the camera lens. Apart from the expense which would be entailed if such a lens were used, a complex camera lens would make the focussing attachment clumsy and heavy. This would be a serious drawback, for portability is one of the principal objects it is desired to achieve.

It has already been mentioned that the telescope eyepiece is so placed that it is in focus on a position in the telescope tube equivalent to the position of the plate in the camera. Actually this is not sufficient in itself to permit of the accurate focussing of the camera, for the eye possesses considerable powers of accommodation. Consequently, it is possible to see clearly an image which is focussed by the front lens of the attachment at a position a little in front of, or behind, the plane corresponding to the position of the plate in the camera. As a result, though a clear image may be seen through the telescope eyepiece, it is quite possible that the image in the camera may be appreciably out of focus.

With the ordinary methods of focussing a camera, this difficulty is overcome by using ground-glass, but ground-glass cannot be used in the focussing attachment here described, for the telescope eyepiece so magnifies the grain of the ground-glass

that the image is obscured. After trying several different methods I now use a plain glass screen on which a number of conspicuous black dots have been placed, consisting of a mixture of Indian ink and Canada balsam. As is shown in fig. 2, this screen (S) is fixed in one end of a tubular carrier (C), in the other end of which the telescope eyepiece (E) is fixed in such a position that it is in focus on the black dots on the screen. This element, consisting of tubular carrier, glass screen and eyepiece, slides into the large end of the telescope tube (T), and is so placed that the black dots of the screen are in the desired position, *i.e.*, a position in the telescope tube equivalent to the position of the plate in the camera.

The eyepiece is mounted in the large end of the telescope tube in order that as large a portion of the image as possible may be seen while using a small telescope tube. Even so, it is obvious that only a small central portion of the image as it appears on the plate of the camera can be seen in the focussing attachment. As a consequence of this arrangement there is much more trouble with reflection from the internal surface of the telescope tube than one experiences with an ordinary telescope. The internal surfaces must be blackened and I have found it necessary to line with black velvet the small component tube which carried the front lens of the attachment. In addition to this, about half an inch of the telescope tube is allowed to project beyond the front lens, so as to form a lens-hood and so to minimise trouble with light falling obliquely on the lens surface.

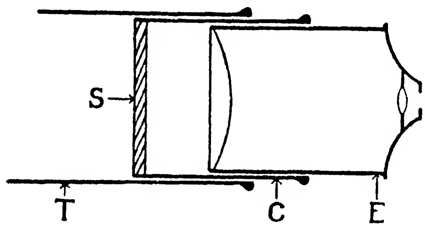


Fig. 2. Longitudinal section of rear end of focussing attachment: C, tubular carrier of focussing screen and eyepiece; E, telescope eyepiece; S, focussing screen; T, telescope tube.

As most insects photographed must necessarily be close to the lens, while the focussing attachment is mounted on the side of the camera, it is necessary that the axes of the camera and of the focussing attachment should converge on the position in which an object is in focus. In order to do this the hind end of the telescope tube is attached to the camera by a hinge (fig. 1, H), while the front end of the attachment can be fixed at any desired position in a special bracket (fig. 1, B). On this bracket are marks showing the position of the front of the focussing attachment which will give the required convergence for any given camera setting. Thus, if the extension of the camera is set up to take a photograph at half natural size, a mark on the bracket shows where the front of the focussing attachment must be set in order to give the necessary convergence.

In fig. 1 it will be noticed that the clamping screw (C_1) which attaches the front of the telescope tube to the bracket (B) passes through a slot of somewhat curious shape. This slot forms a cam which is intended to cause the front lens of the focussing attachment to be always in the correct position to give an image on the glass screen (fig. 2, S) in front of the telescope eyepiece when the camera lens is in focus on the plate and the correct convergence has been set. Actually I did not succeed in making this cam slot of exactly the correct shape, which is a matter of some difficulty. In order to compensate for this, the tubular carrier (fig. 1, C) of the telescope eyepiece and glass screen is made to slide in the end of the telescope tube, and marks are made on the surface of the tubular carrier showing the position in which this carrier should

be fixed in the telescope tube for any given camera setting. With a correctly formed cam slot this should not be necessary, but the mechanism described gives an adjustment which permits of an accurate calibration of the instrument after it has been constructed.

By means of the clamping screws (fig. 1, C_2 and C_3) the focussing attachment can be rapidly attached to, or detached from, the camera. The focussing attachment must, of course, be detached from the camera and carried separately when the camera is folded. It is light and occupies little space when telescoped, so that it adds little to the bulk of the camera outfit.

Certain small modifications are made to the camera itself, in addition to fixing the focussing attachment to it. Marks are made on the sliding basal portion of the camera to show the extension necessary when taking an object at natural size, three-quarters natural size, or any other size required. Also a long lens-hood (fig. 1, LH), consisting of a piece of brass tube lined with black velvet, is slipped over the lens. This is important, for it must frequently happen that the lens more or less directly faces the sun when an exposure is made, and strong light falling obliquely on the surface of a compound lens produces a serious fogging effect on the image. It should be noticed that a much longer lens-hood can be used than would be permissible were the camera used for ordinary subjects. This is because a fairly long bellows extension is always used when photographing insects.

The only remaining modification made to the camera is the attachment of a velvet cover over the back (fig. 1, V). Frequently it is necessary to carry the camera set up ready for instant action, with the cover of the darkslide withdrawn; and one may have to carry the camera so set up and exposed to bright sunlight for a considerable length of time. Under such conditions the velvet cover is absolutely necessary in order to prevent light from creeping round the edges of the darkslide and so fogging the plate. This cover is made in the form of a bag which is attached to the top of the body of the camera and can be slipped over the back of the camera, or removed from it, with ease. It covers the whole of the back and sides of the body of the camera, thus completely preventing any light from falling on the darkslide.

C. *Use of the Field Camera.*

An outline of the manner in which a camera fitted with the focussing attachment is used has already been given, but there are many details to which attention must be paid.

First, one must decide at what size to take the photograph. I find that three-quarters and half natural size are the most generally useful sizes. Only very small objects should be taken at natural size and this is possible only if the light is good. Even if the camera were designed to take photographs at more than natural size, it is doubtful whether the limitations imposed by light and the movement of the object and of the camera would permit of objects being photographed at more than natural size, except in most abnormal circumstances.

Always make allowance for subsequent enlargement. The image should be quite sharp enough to permit of enlargement to two or three diameters, and better results are obtained by taking a small photograph and subsequently enlarging it than by taking it at the size ultimately required. This is because an increased depth of focus, a better exposure and a greater certainty of accurate focus, are obtained when the object is photographed at a reduced size. The selection of the most suitable size at which an object should be photographed needs judgment, and this can be obtained only by experience.

In order to set the camera to take a photograph at the desired size three separate adjustments are necessary; set the extension at the appropriate graduation on the sliding base of the camera, set the front end of the telescope tube at the appropriate

graduation on the front bracket (fig. 1, B) to allow for convergence, and set the tubular carrier of the eyepiece (fig. 2, C) at the appropriate graduation to give the fine adjustment of the focus of the focussing attachment. Now set the stop and shutter of the camera and withdraw the cover of the darkslide and the camera is ready for use.

A few words need to be said about the exposure to be given. Remember that owing to the long extension of the camera longer exposures are required than would be necessary for ordinary snapshots. Also, owing to the closeness of the object to the camera, movement of the image is much more evident than with ordinary photographic work. Consequently fast shutter speeds must be used. I have not found it possible to obtain satisfactory results at speeds of less than 1/50th of a second, and prefer to use a speed of 1/100th of a second. As the depth of focus is normally extremely shallow when photographing insects, one is often tempted to use a small stop and to sacrifice exposure in order to increase depth of focus. Do not make this mistake. Till much faster plates are available, a technically perfect photograph appears to be impossible when using the method here described. Some quality must be sacrificed, and experience shows that it is better to sacrifice depth of focus than exposure.

Also, remember the old photographic adage, " expose for the shadows." My experience under Australian conditions is that almost identical exposures must be given whether the object is exposed to brilliant sunlight or is in a position where no direct sunlight falls. If a photograph is made in intense sunlight and insufficient exposure is given to bring out detail in the shadows, the result will be a hopeless failure, for no subsequent treatment will improve the photograph. On the other hand, even a grossly under-exposed photograph made in dull even light may be made into a passably good photograph by intensification.

Having set the camera and focussing attachment to take a photograph at the desired size and to give the full exposure required under prevailing conditions, everything is in readiness. One points the whole apparatus at the insect, moves it bodily towards or away from the insect till this is seen to be clearly in focus and in the required position, when the exposure can be made. However, considerable practice is necessary before one can focus the apparatus accurately with ease and rapidity, and at first it is advisable to spend some time practising focussing, without exposing, and so wasting, plates.

The major difficulty is due to the fact that the image is reversed in the focussing attachment, just as it is in the camera. Consequently, when movement of the image in the focussing attachment is observed, the beginner accentuates this movement when attempting to check it. The difficulty is the same as that experienced by a beginner when using a microscope.

When making an effort to hold the image stationary and in focus avoid straining and assuming a tense attitude. Such strain causes a rapid vibration of the camera, which will show as movement on the exposed plate. If the camera is held easily and without strain the gentle even movement of the image does not show when an exposure is made. Remember that the movement appears to be much greater than it is, for the telescope eyepiece magnifies the image considerably.

The next difficulty is to make sure that the image and the black spots on the screen (fig. 2, S) are simultaneously in focus. One's attention is apt to be concentrated on the insect, observing whether it is in focus or in the required position, so that one may see the image clearly and make an exposure, overlooking the fact that the black spots are out of focus. If so, the image on the plate will be out of focus. Like the previous one, this difficulty can be overcome only by practice, but the use of very conspicuous dots on the focussing screen is of great assistance.

The technical difficulties so far considered are not of serious importance, for they can soon be overcome by practice. The greatest difficulties one has to contend with

have nothing to do with the photographic apparatus, but are due to the astounding fidgetiness and perversity of insects, and frequently also to wind and the vagaries of daylight. However perfect the photographic apparatus used may be and however expert one may become in using it, the photography of insects must always remain a difficult process, for one cannot hope to be able to make insects or weather conditions behave themselves. Those who are lacking in patience or who cannot afford sometimes to spend an hour or more in making a single exposure will be well advised not to attempt to photograph insects.

Though the apparatus described is sufficient for taking most insects in the field, it is convenient also to carry a reflector. This may be used either to lighten the shadows on the dark side of the object or to throw light on an object which is, for example, in the shadow of foliage. The type of reflector I have found most useful consists of a sheet of polished aluminium on one side of which aluminium foil is cemented. Light reflected from the aluminium foil is strong and beautifully diffuse, while that reflected from the polished surface is more brilliant but not diffuse. Which side is used depends on circumstances.

It is undoubtedly best to have the reflector operated by an assistant, but this is not always possible. However, with practice one can learn to manipulate the camera with one hand, by resting the body of the camera on the shoulder, so leaving the other hand free to operate the reflector. In passing it may be mentioned that ability to manipulate the camera with one hand has other advantages. The free hand may be used to hold back foliage which is casting a shadow on the object, or to pull a branch into a convenient position for photographing some object on it.

The photographs shown in Plates XIV and XIII, fig. 1, are examples of the kind of results one may obtain by using the apparatus which has been described. Plates XIII, fig. 1, and XIV, fig. 3, show that very active insects may be photographed successfully, while Plate XIV, figs. 1 & 2, shows that though one cannot take photographs at more than natural size in the field, it is possible by enlargement to get sufficiently large prints of even very small insects to bring out the details it is desired to show. These two latter photographs were taken at three-quarters of natural size, and efforts to take these same objects at natural size were not so successful.

Photographing Insects by Flashlight.

It has already been mentioned (p.307) that in order to obtain really satisfactory photographs of living insects we require plates many times faster than any at present on the market or, alternatively, a source of light many times more powerful than direct sunlight. When photographing insects in the field during daytime, the most powerful light one can use is direct sunlight, and it is consequently necessary to use larger stops and slower speeds of exposure than are desirable. These limitations have already been considered. If, however, photographs are to be taken at night or in the laboratory one can use a much more powerful illuminant, namely flashlight.

It is a curious fact that it is much easier to obtain thoroughly satisfactory flashlight photographs of insects than of ordinary subjects, such as groups of people. The reason for this is that when photographing an insect the camera is necessarily close to the object, in order that an image of satisfactory size may be obtained, and consequently it is possible to use the flash very close to the object, while still keeping it behind the level of the front of the camera lens. As a result the flash forms a relatively broad source of illumination, so that the illumination of the object is diffuse and there is a remarkable lack of the hard shadows one normally associates with flashlight photographs, as is demonstrated by the photographs in Plates IX–XII, XIII fig. 2, and XV–XVII, all of which were taken by flashlight.

Another result of the closeness of the flash to the object is that the illumination is very intense. For example, by using the amount of flash-powder which can be

heaped on a shilling and firing the flash at about twelve inches from the object one can obtain a fully exposed photograph of natural size, using a stop of f.22 or even f.32. As the length of the flash is about one-fiftieth of a second it is evident that the intensity of illumination is many times that of strong sunlight. Consequently it is possible to obtain fully exposed photographs which possess satisfactory depth of focus at sizes considerably greater than natural size, for much greater quantities of flash-powder than that just mentioned can be used when required.

It is true that under laboratory conditions one might obtain a similar intensity of illumination by using a powerful electric lamp close to the object, and that this would avoid the difficulties introduced by the shock of the flash and the dust it produces. Flashlight has the advantage, however, that it illuminates the object only for the instant when the exposure is made. If a living insect were exposed to light of the intensity of flashlight for even a few moments before the exposure was made, there can be little doubt that the insect would be much disturbed and consequently that the photograph taken would not show it in a natural position.

A further advantage of using flashlight is that no elaborate or expensive apparatus is required. All that is needed is a camera with a long bellows extension and some flash-powder. As very small stops are always used, it is rather an advantage than otherwise to use a small, simple, and consequently inexpensive, lens. The only necessary feature of the camera which can be considered as a special one is a long lens-hood. This is essential in order to prevent any of the light from the flash falling directly on the front of the lens, and a very long lens-hood can be used because small stops and long camera extensions are always used. A very satisfactory lens-hood can be made by rolling a piece of black paper into the form of a tube which can be slipped over the mounting of the camera lens.

In order to take a photograph the camera is set at the necessary extensions to give the required enlargement and is focussed on the object by means of the ground-glass. The necessary amount of flash-powder is then placed as near as possible to the object, in order to obtain the maximum amount of illumination with the minimum amount of flash-powder. The flash must naturally be so placed that as much of the light as possible falls on the side of the object facing the camera, and this necessarily brings the flash rather close to the camera. It is advisable, therefore, to cover with a cloth those parts of the camera which are exposed to the flash. The closeness of the front of the camera to the object naturally causes the flash to be so placed that its light falls obliquely on the object. It is, therefore, advisable to place a reflector on the opposite side of the object and in such a position that it illuminates parts which would otherwise be in deep shadow. A piece of white paper or card makes a very satisfactory reflector.

It is impossible to give any accurate information as to the quantities of flash-powder to use, for different makes of powder differ considerably in the amount of light they produce, and different makes of plates differ markedly in their sensitivity to flashlight in a way which has no direct relation to their speed numbers. However, the quantity of powder used is always quite small, much smaller than would be used for taking portraits, and one or two trial exposures will give the required information for all subsequent work. Having by means of trial exposures determined the amount of flash-powder to be used at a given distance from the object in order to obtain a fully exposed photograph when the camera has a given setting, it is possible to calculate the amount of powder necessary when the camera has any other setting, for example, when it is desired to obtain some other degree of enlargement or to use some other stop. It is important, however, that the quantities of powder used should be accurately measured and that the flash should be placed at exactly the right distance from the object, for the difference of an inch may make a marked difference in the intensity of the illumination on the object.

Having set the camera as described and having placed the necessary quantity of flash-powder in the right position, all that remains to be done in order to take a photograph is to fire the flash-powder. If the object is quiescent and its attitude is of no great importance, as, for example, if the object is a caterpillar, the flash-powder may be fired by lighting with a taper a piece of touch-paper set in the flash-powder. When photographing insects, however, the object is usually not quiescent and it is commonly of importance that it should be photographed in some particular attitude. This being so, it is necessary to be able to leave the apparatus set up for a considerable length of time, and to fire the flash at exactly the instant required.

In the first place, therefore, it is necessary that the flash-powder should remain in good condition even if exposed for a considerable length of time. Many makes of flash-powder very rapidly take up moisture from the atmosphere and become unsatisfactory after exposure for, say, ten minutes. It is necessary, therefore, to find a make of flash-powder which does not take up moisture rapidly. Also some flash-powders give a shorter flash than others, and a make which gives as short a flash as possible should be chosen.

One of the greatest difficulties encountered in developing the method here described has been to find a mechanism which would fire the flash at exactly the moment required and do so with certainty. After experimenting with many different devices I have decided that the most satisfactory type of apparatus is a " flash-gun " in which a powder cap, such as is used in toy pistols, is fired in the flash-powder. The cap is exploded by means of a striker which is released by a trigger. Such " flash-guns " can easily be obtained, for they are used by Press photographers, but I have found that the lightly built cheaper forms are not altogether dependable.

It will be observed that no elaborate apparatus is necessary in order to take flashlight photographs of insects and that the photographic process is simple in the extreme. If the insect to be photographed is quiescent, the whole process of setting up the apparatus and taking the photograph need occupy but a few minutes. However, difficulties arise when, as is usual, the insect is far from quiescent, and much patience and ingenuity is required ; for an hour or more may be spent in waiting for the insect to pause momentarily in the required attitude, while there is ample scope for inventing and using " dodges " to make the insects behave as required.

Before passing on to deal with the use of flashlight photography under field and laboratory conditions, mention must be made of an important and very satisfactory character of flashlight. The actinic rays of flashlight lie almost wholly within the visible spectrum and, as a result, panchromatic plates are particularly sensitive to it, while ordinary plates are relatively insensitive. For example, during the development of the flashlight method described I used a very fast orthochromatic plate. Later I tried a panchromatic plate with less than half the nominal speed of the plate previously used and discovered to my astonishment that it actually required only half the exposure necessary for the orthochromatic plate. It is advisable, therefore, to use panchromatic plates, for not only are they faster than other types of plates, but they give true colour renderings, this being most noticeable for reds and yellows, and the quality of the negative is far superior to that of fast plates of other types.

Flashlight Photography in the Field.

When looking for insects in the field at night one is immediately struck by the fact that the visible insect population is very different from that observed in daytime. Most of the insects which are obvious during the day have disappeared, and other insects which are hidden during daylight are most obvious. Also, certain activities of insects are carried out only at night, for example, the egg-laying, emergence and feeding of particular species. Consequently if one wishes to illustrate the lives of insects, it is highly desirable that photographs should be taken at night.

A curious and most noticeable fact is that insects which are hidden during the day and scuttle for cover if disturbed are often found in the most conspicuous positions at night, as, for example, on the extreme tips of grasses and the tops of bushes, where they remain quiescent. Such insects are commonly not easily disturbed, and as a result it is possible to set up a camera on a stand, to focus on the insect in the ordinary way, and to take a photograph at leisure. The fact that the air is frequently still at night is also of assistance. As a consequence there is no great need to be able to follow the movements of insects with the camera, as there is in daytime.

All that is necessary in order to take photographs of insects in the field at night is a powerful lantern, to be used when searching and later when focussing, a camera with a long bellows extension, some flash-powder, and some simple apparatus for firing the powder. As most of the objects to be taken are quiescent, a very simple firing apparatus can be used. The one I have used principally consists of a small elongate tray into one end of which a taper is clipped while the flash-powder is placed at the other end. The tray is mounted on a handle and to fire the flash one simply lights the taper and then tips the tray so that the powder falls on the flame of the taper. This apparatus was used when taking the photographs shown in Plates IX and X.

As to the camera, any light field-camera will do, provided that it has a sufficiently long bellows extension. A reflex camera would probably be rather better than an ordinary camera. Personally I use the same camera as that for taking snapshots in the daytime, and the focussing attachment already described is useful for re-focussing if the insect moves slightly or if it is suspected that the camera has been moved, but this attachment is not essential.

Attention should be paid to reflecting light on that part of the object which would otherwise be in shadow, for unless this is done the results may be rather harsh and detail may be lost. If no special background is placed behind the insect, the background will naturally appear black in the photograph. While this is often perfectly satisfactory, more pleasing results can usually be obtained by placing a sheet of white card at some distance behind the object. Photographs taken in this way can scarcely be distinguished from those taken in daylight, as is demonstrated by Plate X.

Flashlight Photography in the Laboratory.

Under laboratory conditions one can use heavier and more bulky apparatus than is possible in the field. Consequently photographs of insects can be taken at greater degrees of enlargement. It is also possible to take photographs by flashlight while working in broad daylight or strong artificial light. This is due to the fact that flashlight is so much more powerful than the diffuse daylight or artificial light in the laboratory. When the camera is set at the long extension and small stop required for flashlight, it would probably be necessary to make an exposure of an hour or more in order to take the photograph by means of the diffuse light in the laboratory. One may therefore open the shutter and leave it open for several minutes before firing the flash and yet the only impression on the plate will be made at the instant the flash is fired, for the exposure to daylight is insufficient to produce any effect. However, when using white backgrounds one must be careful not to leave the shutter open for long periods, as otherwise confusing silhouettes of the insect may appear on the plate. The convenience of being able to take flashlight photographs while working with ample light in which to observe the insect to be photographed, and to see the apparatus one is using, must be obvious.

Any ordinary laboratory camera with a long bellows extension may be used, but, particularly when taking photographs at a considerable magnification, it is desirable that the camera should be of robust construction and that all parts should be held firmly in position. A loose lens or darkslide carrier may be caused to vibrate by the shock of the flash and so spoil the photograph.

The shock produced when flash-powder is ignited limits the degree of direct enlargement. My experience has been that when ordinary opaque objects are taken at an enlargement of more than about three diameters the effects of shock become evident in the photographs. However, if semi-transparent objects, such as many aquatic animals, are photographed, it is possible to obtain an enlargement of as much as six diameters, as was done with the mosquito larva shown in Plate XVII (the photograph of which was, of course, subsequently further enlarged). This is possible because such semi-transparent animals are actually photographed by strong transmitted light which is reflected from the white background, and the amount of flash-powder required when photographing an opaque object at an enlargement of three diameters is quite sufficient for photographing semi-transparent objects at six diameters.

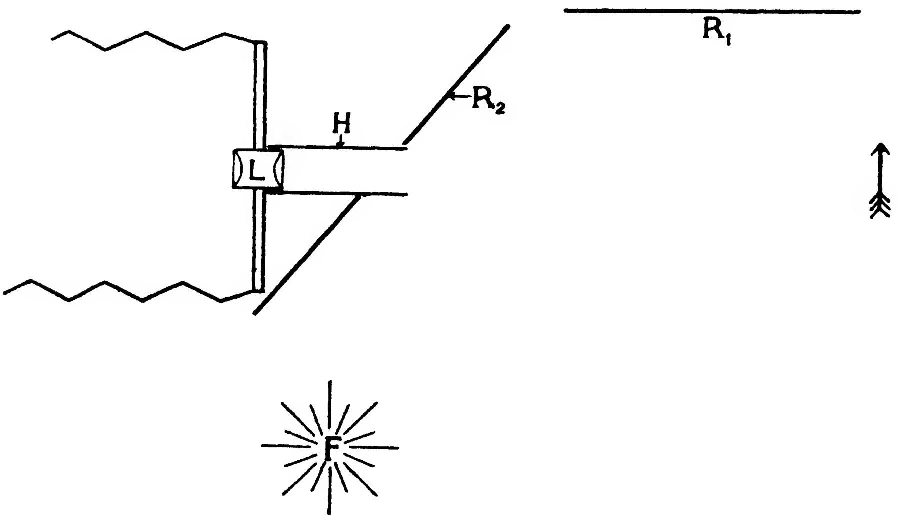


Fig. 3. Diagram showing arrangement of reflectors: F, flash; H, lens-hood; L, camera lens; R_1, side reflector; R_2, front reflector attached to lens-hood; the object is indicated by an arrow.

It is possible that some method may be devised for reducing the shock of the flash, or its effects. The obvious method is to interpose a sheet of glass between the flash and the camera, but I have been unable to observe any improvement when this method is used.

It is important that proper use should be made of reflectors. In addition to using a reflector (fig. 3, R_1) so placed that it reflects light on those parts of the object which would otherwise be in shadow, it is often advisable to use a small reflector (fig. 2, R_2) which consists of a piece of white paper or cardboard mounted on the lens-hood. It is placed obliquely on the lens-hood in such a position that it catches light from the flash and reflects this directly from the camera on to the front of the object.

When photographing an object through glass, difficulty may be experienced owing to reflections from the surface of the glass, which reduce the clarity and may obscure the detail of the object photographed. These are actually dim images of the lens and other fittings of the camera. To overcome this difficulty, cover a piece of cardboard with black velvet. Through the middle of the velvet-covered card cut a hole distinctly larger than the stop to be used and surround the card with a wall of black paper sufficiently high to shield the velvet from the direct light of

the flash. This structure is fitted in front of the lens, as is shown in fig. 4. The object reflected in the glass is now black velvet in shadow, instead of bright camera fittings, and consequently the reflections do not obscure the object to be photographed.

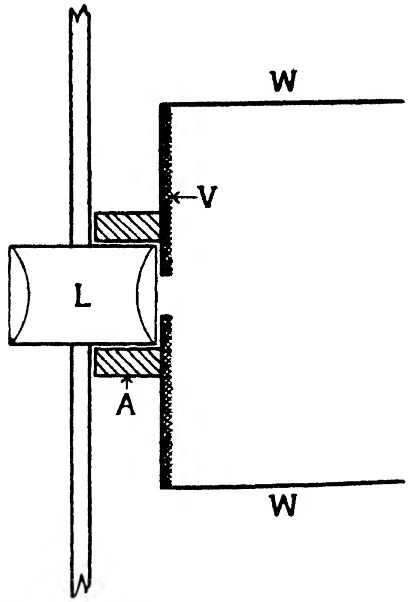


Fig. 4. Longitudinal section of apparatus used to overcome difficulties with reflections: A, adapter; L, camera lens; V, card covered with black velvet; W, walls of black paper.

Even with this fitting there is necessarily a small area of lens exposed and the reflection of this may cause trouble, particularly if the object is a dark one photographed against a light background. To deal with this, slide the lens to one side so that the axis of the lens is opposite the edge, instead of the middle, of the plate.

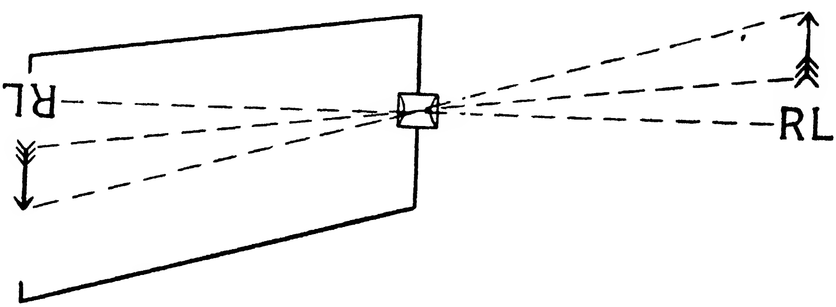


Fig. 5. Diagram showing method of dissociating the object, indicated by an arrow, and the reflection of the camera lens, RL. The images in the camera are indicated on the left.

This arrangement is shown in fig. 5, and it will be seen that the reflection (RL) of the lens in the glass will throw an image on the edge of the plate, so leaving the image of the object (indicated by an arrow) unobscured. The same arrangement also removes the difficulty caused by a " flare spot " which is due to the internal reflection of light in a complex lens.

Much attention needs to be paid to the proper use of backgrounds. A white background should be placed at a considerable distance away from the object, not only to avoid the appearance of the shadow of the object in the photograph, but also to reduce the intensity of the light reflected from the background. Unless care is taken the light from a white background will probably be too intense and will obscure detail on the edges of the object. A better white background in a photograph can usually be obtained by using dark grey paper, instead of white, for the background. If a black background is required, it is useless simply to place a sheet of black paper behind the object, for this will probably appear almost pure white in the photograph. Use a large black-lined box with a hole in the front only large enough to provide the necessary background. The object is then photographed against darkness and a pure black background is obtained in the photograph.

A few words may be said as to how to hold the object to be photographed in the required position. Many objects are photographed on twigs or other parts of plants, and these may conveniently be held in a lump of plasticine, for this material permits one readily to move the object into any position desired. Another convenient method is to mount the camera vertically, with the lens pointing downwards, and to support the object on a sheet of glass placed at some distance above the background.

A particularly convenient piece of apparatus can be made by taking two cleaned quarter-plate negatives and cementing glass strips between them on three sides with balsam. This may be used either as a small narrow tank for aquatic insects or as a glass cage for non-aquatic insects. Several such tanks should be constructed with different degrees of narrowness, the distance between the sides being determined by the number of glass strips, piled one above the other, which are used. A variation of this is to cement piles of glass strips on the four sides of a single cleaned negative. This makes a convenient shallow tank in which to photograph aquatic insects from above.

The photographs in Plates XIII, fig. 2, XI, XII, and XV–XVII illustrate the kind of results one may obtain under laboratory conditions when using the flashlight method. They show that though the maximum possible direct enlargement when using this method is not great, yet photographs quite large enough for most purposes can be obtained, particularly if enlargements are subsequently made from the negatives. Other points demonstrated are the softness of illumination, the absence of hard shadows, and the fact that the interposition of glass or water between the object and the camera does not obscure detail. The life-history of the mosquito illustrated by Plate XVI also demonstrates that there is little loss of light when insects are photographed through glass and water, for the adult mosquito is above the glass tank, the surface of the water being level with the top of the tank. The photographs shown in Plates XIII, fig. 2, XI, XII, XV, fig. 1, XVI and XVII were taken by my former assistant, Miss G. Burns, under my direction, and she deserves much credit for the results achieved, for all the insects shown in these photographs are particularly restless ones. Almost infinite patience and much skill is necessary in order to obtain such results.

Photographic Points of Importance.

When carrying loaded darkslides in the field there is not only a danger that light may get to the plates, but also that dust may get into the darkslides and, by settling on the surface of the negatives, cause the appearance of " pin holes " when the plates are developed. One should always carry the darkslides wrapped in paper, preferably strong brown paper. This excludes light and dust and helps to preserve the plates from the effects of changing atmospheric conditions. In practice, however, it is found that dust will often get into the darkslides in spite of this precaution.

I have found the following method of dealing with the dust problem particularly satisfactory. Obtain a large soft brush and moisten it so slightly with turpentine that it will scarcely produce a smear. Before loading the plates, brush the inside of the darkslides and it will be found that all the dust will be picked up by the brush while a very thin film of turpentine is left in the darkslide. Any dust which subsequently gets into the darkslide sticks to this film and so leaves the surface of the negative clean. Turpentine does not appear to have any effect on photographic plates. This method is almost essential when using flashlight, for the flash produces large quantities of dust, some of which always gets into the darkslides. The quantity of dust produced is the greatest drawback to the use of flashlight, but benches, shelves, etc., can readily be cleaned by using a large brush, or a duster, slightly moistened with turpentine.

No special developers are necessary for insect photography. Obtain a fully exposed plate and use the developer best suited to the plate and the character of the object photographed. I find pyro-soda the most generally useful developer, but pyro-metol gives somewhat better results if the plate is exposed in dull light, particularly if it is somewhat under-exposed.

When working under tropical conditions, difficulty is often experienced owing to the effects of moisture on the plates. This difficulty may be overcome by wrapping a small quantity of anhydrous copper sulphate in blotting-paper and inserting this in the box with the plates or films. If these are in airtight containers it is well to let the copper sulphate remain with them for only a day or two and then to remove it and seal the containers, for in time the copper sulphate will desiccate the plates. The anhydrous copper sulphate is produced by heating ordinary copper sulphate crystals till all the water of crystallisation is driven off, so leaving a white powder.

Incidentally, it may be remarked that anhydrous copper sulphate is a most useful substance to the entomologist working in moist climates. By placing quantities of this in specimen boxes, the specimens collected can be dried very rapidly, so preventing rotting and the development of mould, but it is advisable not to leave the specimens exposed to the copper sulphate indefinitely, for they will become desiccated and very brittle.

Explanation of Plate XV.

Fig. 1. *Musca domestica*, L., feeding on a drop of honey supported on bread. Note the corona of saliva round the labella (x 10).

Fig. 2. Larva of the dragon-fly, *Austrolestes analis*, eating a Chironomid larva. The structure on which it is resting is a piece of white card, which partly conceals the Chironomid (x 6).

The field camera and focusing attachment in use.

A long-horned grasshopper, Gryllacris sp., drying itself after having cast its skin, at night (x 1.6).

Larva of the Lycænid butterfly Ialmenus evagoras with attendant ants, Iridomyrmex sp., at night (x 3).

Larva of Chrysopa otalatis (?) sucking juices from rose-aphis.
Note the empty skins of aphids piled on its back (x 9).

Larva of Syrphus ortas, Wied., eating an orange-aphis (x 9).

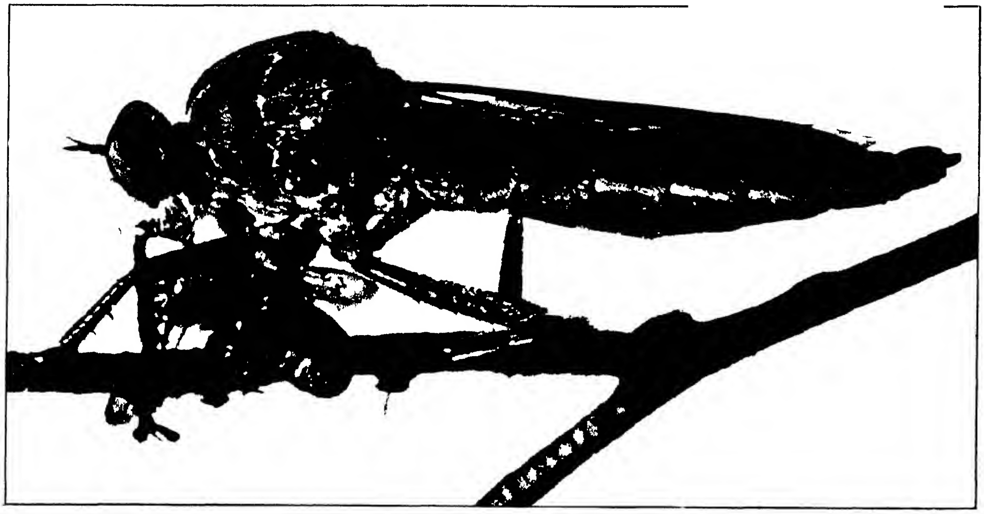


Fig. 1. The Asilid, Neoaratus hercules, Wied., sucking juices from honey-bee (x 3).

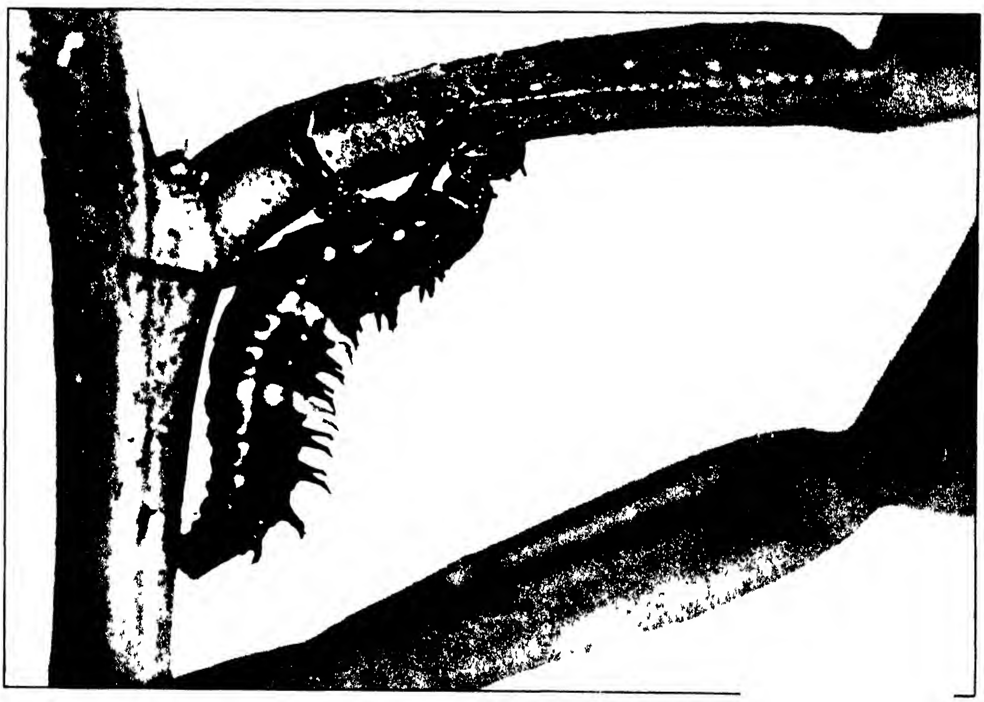


Fig. 2. Larva of the Coccinellid, Leis conformis, Boisd., eating an orange-aphis (x 10).

Fig. 1. The Leptid, Spaniopsis longicornis, Ferg sucking blood from finger (x 4).

Fig. 2. Aedes (Finlaya) alboannulatus, Macq., sucking blood from finger (x 4).

Fig. 3. The Nemestrinid, Trichophthalma confusa, Mack., hovering in mid-air (x 2).

Fig 1

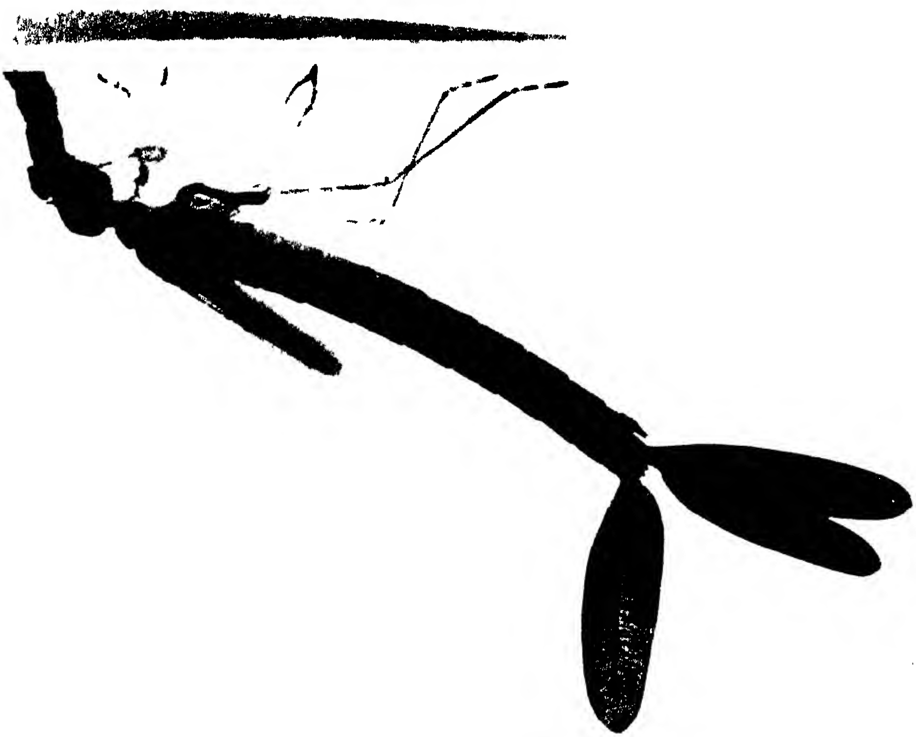
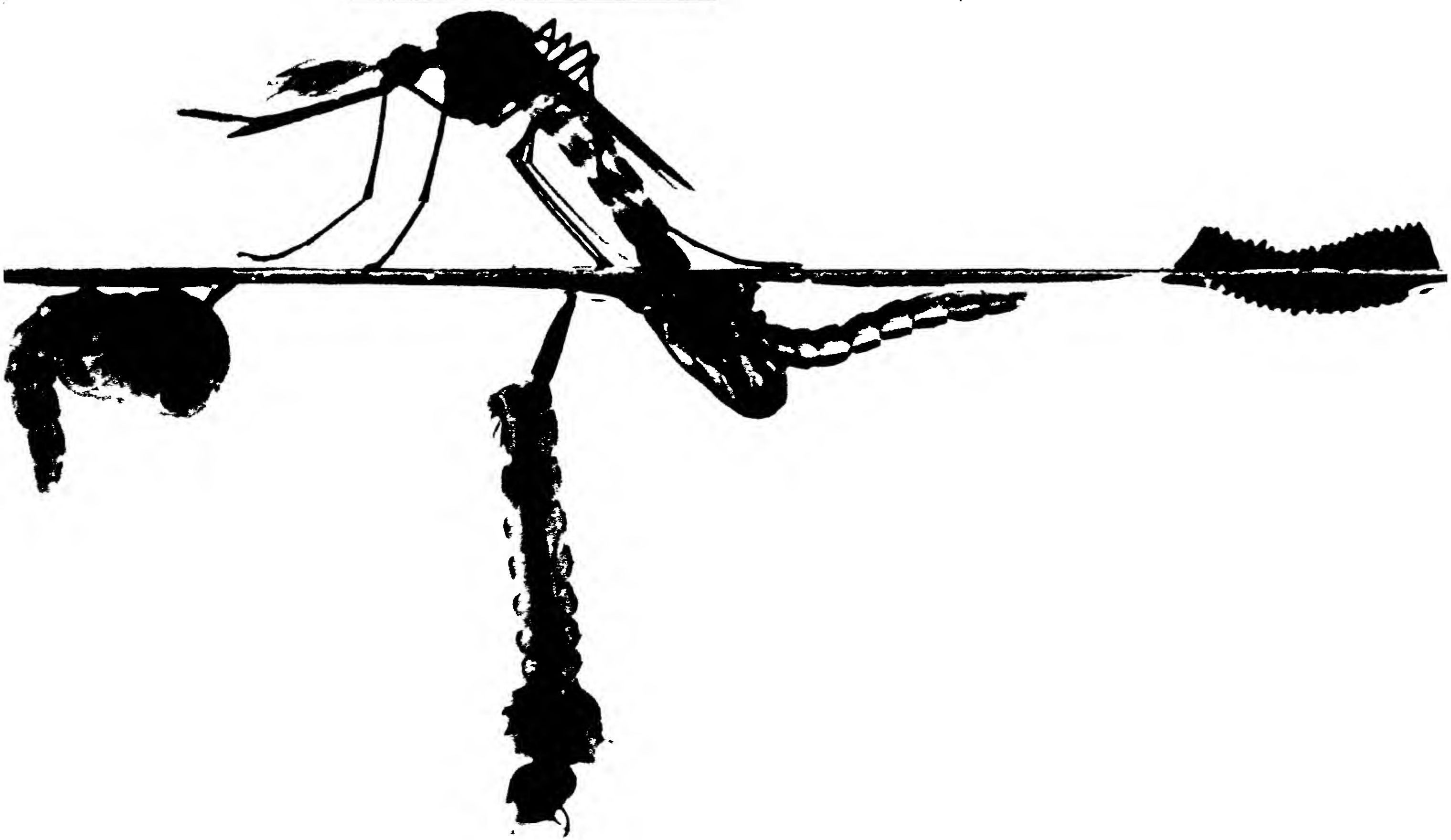
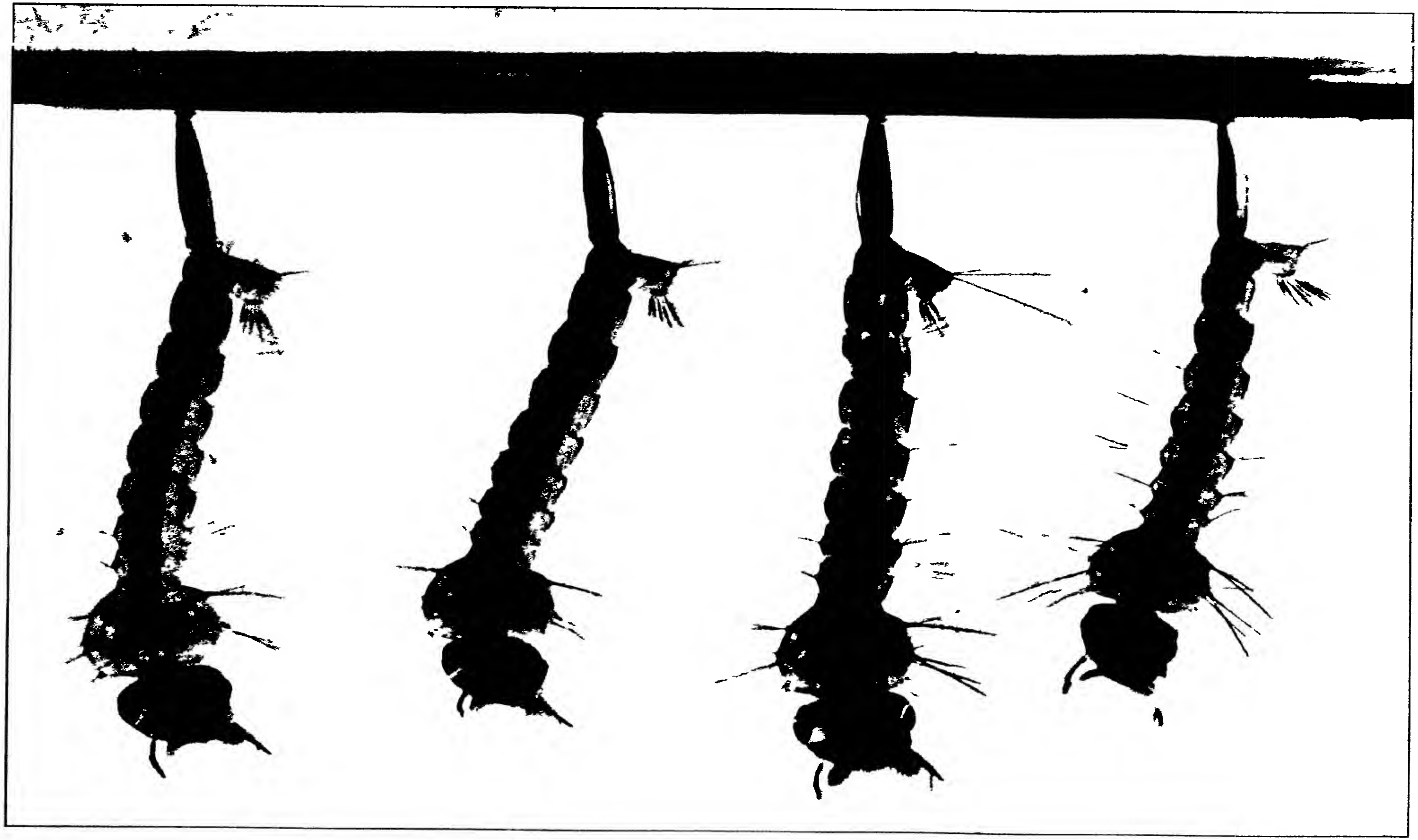


Fig. 2.



The life-history of Culex fatigans, Wied. (x 13).



Larvæ of Culex fatigans, Wied. The dark structure above is the meniscus of the water (x 17).

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology, between 1st January and 31st March, 1931, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Dr. T. V. Ramakrishna Ayyar, Assistant Entomologist :—116 Coleoptera ; from South India.

Prof. H. A. Ballou :—3 Diptera, 22 Coleoptera, 21 Parasitic Hymenoptera, and 2 Lepidoptera ; from Trinidad.

Mr. P. J. Barraud :—10 Culicidae, 11 slide preparations of genitalia, and 58 other Diptera ; from the Punjab, India.

Mr. A. H. Bastin :—15 Dipterous larvae ; from Berkshire.

Dr. Max Beier :—27 Parasitic Hymenoptera ; from Austria.

Dr. Blunck :—10 Chalcididae ; from Germany.

Mr. G. E. Bodkin, Government Entomologist :—109 Diptera, 4 Coleoptera, 25 Parasitic Hymenoptera, 19 other Hymenoptera, 241 Lepidoptera, 40 Isoptera, 5 species of Aphidae, 238 other Rhynchota, 5 Orthoptera, 28 Planipennia, and 7 Odonata ; from Palestine.

Dr. G. Bondar :—35 Coleoptera ; from Brazil.

Mr. H. E. Box :—2 Diptera, 44 Coleoptera, 124 Hymenoptera, 3 Lepidoptera, and 4 Rhynchota ; from various localities.

Dr. P. A. Buxton, London School of Tropical Medicine :—100 Culicidae, 37 Tabanidae, 247 *Stomoxys*, and 73 other Diptera ; from various localities.

Dr. A. E. Cameron :—3 Diptera ; from the Gold Coast.

Dr. G. D. H. Carpenter :—22 Curculionidae ; from Nganiland.

Dr. A. Chiaromonte :- 10 Coleoptera, 5 Lepidoptera, 2 Rhynchota, and 5 Orthoptera ; from Italian Somaliland & Eritrea.

Chief Entomologist, Pretoria :—2 Diptera, 65 Coleoptera, 72 Parasitic Hymenoptera, 2 species of Coccidae, and 2 species of Aleurodidae ; from South Africa.

Mr. L. D. Clearf, Junr., Government Entomologist :—4 Diptera ; from British Guiana ; and 29 Parasitic Hymenoptera ; from Trinidad.

Prof. T. D. A. Cockerell :—2 Diptera, 15 Coleoptera, 7 Parasitic Hymenoptera, 32 other Hymenoptera, 10 Lepidoptera, and 7 Rhynchota ; from various localities.

Mrs. S. L. M. Connal :—14 Culicidae and 6 slide preparations of early stages ; from Nigeria.

Mr. G. H. Corbett, Government Entomologist :—33 Diptera, 74 Coleoptera, 50 Parasitic Hymenoptera, 67 Lepidoptera, 2 Isoptera, 2 species of Coccidae, 1 species of Aphidae, 13 other Rhynchota, 3 Orthoptera, and 500 Mites ; from Malaya.

Coryndon Memorial Museum, Nairobi :—644 Coleoptera ; from Kenya Colony.

Mr. D. S. Cowan :—2 Scolytidae ; from England.

Mr. A. Crèvecoeur :—24 Parasitic Hymenoptera ; from Belgium.

Mr. A. Cuthbertson, Assistant Entomologist :—3 Culicidae, 6 Asilidae and their prey, 22 other Diptera, 3 Coleoptera, 2 Parasitic Hymenoptera, 3 other Hymenoptera, and 5 Rhynchota ; from Southern Rhodesia.

Mr. P. R. Dupont :—18 Diptera and 1 species of Coccidae ; from the Seychelles.

Mr. W. H. Edwards, Government Entomologist :—4 Diptera, 6 Coleoptera, 7 Parasitic Hymenoptera, 3 Lepidoptera, 8 Rhynchota, and 2 Orthoptera ; from Jamaica.

Mr. J. C. M. Gardner, Systematic Entomologist :—122 Curculionidae, 797 Parasitic Hymenoptera, 6 Lepidoptera, 16 Psyllidae, and 298 other Rhynchota ; from the United Provinces, India.

Mr. C. C. Ghosh :—1 species of Aphidae and 8 other Rhynchota ; from Burma.

Dr. Athos Goidanich :—3 Parasitic Hymenoptera ; from Italy.

Mr. F. D. Golding, Government Entomologist :—4 Coleoptera, 16 Lepidoptera, 1 species of Aleurodidae, and 9 other Rhynchota ; from Southern Nigeria.

Government Entomologist, Lyallpur :—3 Hymenoptera, 21 Lepidoptera, 19 Rhynchota, 116 Orthoptera, and 10 Planipennia ; from the Punjab, India.

Mr. W. GREENWOOD :—2 Coleoptera, 124 Lepidoptera, 3 Rhynchota, and 3 Trichoptera ; from the Fiji Islands.

Mr. G. J. HAEUSSLER :—29 Parasitic Hymenoptera ; from France.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—7 Diptera, 1,003 Coleoptera, 3 Parasitic Hymenoptera, 315 Lepidoptera, 8 Rhynchota, 123 Orthoptera, and 6 Dermaptera ; from Uganda.

Mr. E. HARGREAVES, Government Entomologist :—6 Tabanidae, 67 other Diptera, 161 Coleoptera, 536 Parasitic Hymenoptera, 28 other Hymenoptera, 338 Lepidoptera, 1 species of Coccidae, 1 species of Aphidae, 127 other Rhynchota, 184 Orthoptera and a number of eggs, 2 Dermaptera, 8 Planipennia, 4 Ephemeridae, 38 Trichoptera, 50 Mites, and 4 Parasitic Worms ; from Sierra Leone.

Mr. H. HOCKINGS :—3 Coleoptera ; from Queensland, Australia.

Mr. G. H. E. HOPKINS, Medical Entomologist :—124 Culicidae, 793 Coleoptera, and 674 Rhynchota ; from Uganda.

Dr. J. C. HUTSON, Government Entomologist :—17 Coleoptera ; from Ceylon.

Mr. F. P. JEPSON, Assistant Entomologist :—500 Diptera ; from Ceylon.

Mr. K. H. L. KEY :—7 Diptera and 68 Orthoptera ; from South Africa.

Mr. W. R. S. LADELL :—3 Diptera, 2,006 Coleoptera, and 20 Rhynchota ; from Siam.

Mr. O. B. LEAN, Assistant Entomologist :—246 Orthoptera ; from the Gold Coast.

Dr. S. LEEFMANS :—6 Diptera, 40 Parasitic Hymenoptera, 16 Lepidoptera, and 9 Rhynchota ; from Java.

Mr. H. M. MORRIS, Government Entomologist :—6 Lepidoptera, 85 Orthoptera, and 6 Planipennia ; from Cyprus.

Mr. J. MUGGERIDGE : —4 Culicidae, 224 other Diptera, 88 Coleoptera, 100 Collembola, and 2 Mites ; from New Zealand.

Dr. J. G. MYERS :—3 Diptera ; from the West Indies.

Prof. G. H. F. NUTTALL, F.R.S.—81 *Glossina* and 3 other Diptera ; from Portuguese East Africa.

Mr. R. W. PAINE :—4 Braconidae and 45 Lepidoptera ; from Java.

Prof. G. PAOLI :—2 Coleoptera and 6 Parasitic Hymenoptera ; from Italian Somaliland.

Mr. W. H. PATTERSON :—3 Coleoptera and 31 tubes of Aleurodidae and their parasites ; from the Gold Coast.

Mr. R. H. LE PELLEY, Assistant Entomologist :—292 Parasitic Hymenoptera and 32 Lepidoptera ; from Kenya Colony.

Mr. A. W. J. POMEROY, Medical Entomologist :—26 Culicidae ; from the Gold Coast.

Mr. A. H. RITCHIE, Government Entomologist :—17 Rhynchota and 4 Orthoptera ; from Tanganyika Territory.

Mr. J. I. ROBERTS, Medical Entomologist :—30 Siphonaptera, 186 Culicidae, 900 other Diptera, 2 Hymenoptera, 3 Rhynchota, 88 Mammal skins, and 500 Worms ; from Kenya Colony.

Mr. R. SALGUES :—10 packets of Galls ; from France.

Mr. H. W. SIMMONDS :—10 Tabanidae, 321 other Diptera, 40 Coleoptera, 28 Parasitic Hymenoptera, 104 other Hymenoptera, 51 Lepidoptera, 58 Rhynchota, 6 Orthoptera, 3 Planipennia, and 2 Odonata ; from South Africa.

Mr. E. R. SPEYER :—80 Diptera and 10 early stages, 3 Coleoptera, 2 Thysanoptera, 1 species of Coccidae, 30 Collembola, and 16 Symphylidae ; from England.

Mr. F. W. URICH :—2 Diptera ; from Trinidad.

Mr. P. VAYSSIÈRE :—3 Parasitic Hymenoptera , from France.

Dr. WALRAVENS :—7 *Glossina* ; from the Belgian Congo.

Mr. A. WETMORE :—33 Parasitic Hymenoptera ; from the United States of America.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—35 Diptera, 79 Coleoptera, 12 Parasitic Hymenoptera, 110 other Hymenoptera, 50 Thysanoptera, and a number of Mites ; from the Sudan.

FURTHER STUDIES ON LEAF-CURL OF COTTON IN THE SUDAN.

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(Plates XVIII & XIX.)

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1.

In a previous paper[7] the writer gave a short account of "leaf-crinkle" of cotton in the Gezira area of the Sudan, and showed that the condition was due to a virus disease carried specifically by white-flies. Further work during the past year has resulted in a considerable addition to our knowledge of this disease, of which the present paper is an account.

The writer has inadvertently been responsible for some little confusion as to the popular name by which this virus disease should be known, as in his preliminary account of the method of transmission of the virus he used the term "leaf-crinkle"—as proposed by Dr. F. G. Gregory, of the Imperial College of Science, during his visit to the Sudan in 1928–29. This name was adopted partly because it was more descriptive of the symptoms as they are manifested on Sakel cotton, and partly because Massey had implied[9] and stated positively[10] that "leaf-curl" at Shambat, near Khartoum, was definitely carried by JASSIDAE. He also gave it as his opinion that white-flies were unlikely to be, or even incapable of being, vectors of the disease.*

It was thought scarcely credible that the same virus disease, however similar the symptoms, should be carried exclusively by ALEURODIDAE in the Gezira, and exclusively by JASSIDAE at Shambat; this therefore appeared to be in itself a sufficient reason for rejecting the name "leaf-curl" for the disease in the Gezira.

Moreover, the London Supervisory Committee for the co-ordination of Agricultural Research in the Sudan recommended that the term "leaf-crinkle" be adopted in preference to that of "leaf-curl."[23]

It subsequently appeared that none of Massey's remarkable statements that the disease was carried by JASSIDAE was based on any sort of adequately controlled transmission experiments; and, as will be shown in the present paper, the disease at Shambat is transmitted, as it is in the Gezira, by white-flies, no single instance of transmission by JASSIDAE having been obtained.

Furthermore, it is exceedingly probable that this virus disease of cotton in the Sudan is the same as that in Nigeria, described originally by Farquharson[4] and later by Jones & Mason[6] as "leaf-curl." Additional weight is given to the probability of the diseases in the two countries being identical by the fact that Golding,[5] simultaneously with but entirely independently of the present writer, proved that the disease in Nigeria is carried by white-flies. It is true that the symptoms of the disease in Nigeria are by no means exactly similar to those in the Sudan; for instance, Jones & Mason[6] described as the most important characteristic of "leaf-curl" on *Gossypium peruvianum* and *G. vitifolium* "a strong upward curl of the leaf margin." This feature is not particularly noticeable on Sakel cotton in the Gezira and is never the most characteristic sign of infection—if infected Sakel leaves are curled at all, they are quite often curled downwards instead of upwards. Other points in which the manifestation of the disease on Nigerian cottons differs from that on Sakel are the absence in the former of any twisting of the petioles, and the rarity of net-vein enations on the bracteoles—a practically universal feature of the disease in Sakel, even if a plant is otherwise only mildly affected. Also the leaves of affected Sakel cotton are never "savoyed" light and dark green. Such differences are, however, no doubt due to the different varieties of cotton grown in the two countries, and are no greater than might be expected.

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* "White Fly were rare during the past season, so that even if they were capable of transmitting the disease, they were definitely not the main vector. Feeding experiments with White Fly brought from diseased plants in the Gezira were consistently negative, and it is believed that the feeding habits of the White Fly do not fulfil the necessary requirements. There remains therefore only the ubiquitous Jassid" (9, p. 78).

It should perhaps be mentioned that, as emphasized by Salaman[16, 17] and others, there is no proof that somewhat similar symptoms in different varieties of a plant are the result of infection by the same virus, unless one variety has been definitely infected from the other. Until opportunity occurs to infect plants grown from Nigerian strains of cotton liable to " leaf-curl " by means of white-flies infected with the " crinkle " manifestation of the disease on Sudan Sakel, and to note if the resulting symptoms correspond to those of the Nigerian " leaf-curl," the identity of the Sudan disease with that in Nigeria cannot be considered absolutely proved.

On certain other types of cotton, *e.g.*, on Watts Long Staple (*G. hirsutum*), the symptoms of the disease (as is fully explained in Section 23) are totally unlike those on either Sakel in the Sudan or on *G. peruvianum* or *G. vitifolium* in Nigeria; so different are they that were it not for the fact that mosaic can be regularly produced on Watts Long Staple by infection with white-flies from crinkly Sakel, no connection between the two could be imagined. (Compare the diseased leaves figured in Plate I with those in Plate II.) It is therefore obvious that no single name can be applied to the disease which is descriptive of the symptoms as manifested on all its host-plants.

On the advice of Dr. E. J. Butler, Director of the Imperial Institute of Mycology, to whom the writer's thanks are due for the trouble he has taken in discussing this matter, it is now proposed that " leaf-curl " should be adopted as the name of this virus disease, as this name has been more widely used in previous literature and in the Review of Applied Mycology.

It must be emphasized that the *name* of the disease will be the same for all host-plants, even though on many of them little or no " curling " of the leaves is manifested. The *symptoms* of the disease will be described as follows: " Curl " for a definite curling of the leaf margins, either upward or downward as specified; " crinkle " for the peculiar crinkled appearance produced by the " net-vein enations " which is the most characteristic feature of the disease on Sakel cotton (Plate XVIII); and " mosaic " for the chlorotic spots which appear on certain varieties of cotton when these are infected with the virus of leaf-curl (Plate XIX).

2. Notes on Previous Literature possibly connected with Leaf-curl.

(1) In 1912 Aulmann[1] refers to the statements of Zimmermann, Vosseler & Kränzlin (to the original publications of whom the present writer has not been able to refer) regarding " Kräuselkrankheit " of cotton in (then) German East Africa.

It appears almost certain, as Zimmermann is quoted as saying, that several distinct diseases of cotton have been referred to as Kräuselkrankheit, and it is very probable that the one which Kränzlin is quoted as having proved to be due to JASSIDAE is the condition resulting from direct damage by Jassids as described by Parnell[15] in South Africa.

There seems to be no certain evidence that any of the conditions which have been referred to as Kräuselkrankheit in East Africa are similar to the Sudan leaf-curl.

It may also be mentioned that the present writer, in the course of three tours of inspection of the cotton-growing areas on the coast of Kenya between Mombasa and Mambrui, during 1926 and 1927, never noticed any condition similar to either " crinkle " or " mosaic " as it occurs in the Sudan.

(2) Farquharson,[4] in 1912 and 1913, was the first to describe leaf-curl in Nigeria. As stated in Section 1, there is a strong probability, but as yet no proof, that this disease is the same as that dealt with in the present paper.

(3) Jones & Mason[6] paid more attention to leaf-curl in Nigeria, and tentatively connected a " bunchy top " and mosaic condition of American cotton (*G. hirsutum*)

with the "curl" of *G. peruvianum* and *G. vitifolium*. (This mosaic condition is somewhat similar to, but not identical with, the mosaic that appears on certain strains of American cotton when infected by white-flies with the virus of leaf-curl in the Sudan.) They also indicated that leaf-curl was an infectious virus disease.

(4) Massey[8] first recorded the disease from the Sudan, under the name "leaf-curl." Two other papers[9, 10] on the subject by the same writer are based on the assumption that Jassids are the vectors of the disease.

(5) Misra & Lamba[12] describe as a new species the cotton white-fly (*Bemisia gossypiperda*) and give notes on its habits and life-history in the Punjab. The white-fly occurring on cotton in the Sudan, which is the sole vector of leaf-curl, has since been identified as this species by the Imperial Institute of Entomology.

(6) Paoli,[14] writing about "Aricciamento" of cotton in Italian Somaliland, is undoubtedly referring, at any rate for the most part, to direct damage by JASSIDAE.

(7) Golding[5] in Nigeria adduced evidence that "leaf-curl" of *G. peruvianum* and *G. vitifolium* could be conveyed by an unidentified species of Aleurodid, and indicated that JASSIDAE were unlikely to be vectors.

Apart from the article by Golding[5] already mentioned, and the present writer's previous paper,[7] the only references to white-flies as carriers of virus diseases appear to be the following :—

(1) Bewley[2] claims to have transmitted tomato mosaic by the agency of *Trialeurodes vaporariorum.*

(2) Smith[18] obtained evidence that the same species of white-fly was an occasional vector of potato mosaic, but states that "further work with these insects is required before definite conclusions are drawn."

(3) Blattny[3] suggested that a mosaic disease of Lily of the Valley might possibly be transmitted in greenhouses by *T. vaporariorum*, but no proof of its being a carrier was obtained.

3. Further Proof of Transmission of Leaf-curl by White-flies.

Owing to the various statements which have been published alleging that this disease is carried by Jassids, not one of which, at any rate in this country, has been based on controlled experiments, it is thought advisable to give a complete summary of all the straightforward transmission experiments of leaf-curl from Sakel cotton to Sakel by means of white-flies.

Experiment No. 1.

Plants grown in water-cultures, completely protected by lamp-glasses and organdie muslin.

White-flies used had been bred on crinkly Sakel plants and were left on the plants to be infected.

(*a*) More than ten white-flies transferred to each plant ; experiments carried out February to June, 1930.

Thirty-one separate experiments on 40 plants, resulting in 30 successful transmissions to 39 plants. The single failure was on a yellow, rather badly growing plant.

(*b*) Less than ten white-flies transferred to each plant ; experiments carried out April to June, 1930.

One successful transmission			with	7	white-flies.	
One	,,	,,	,,	6	,,	,,
One	,,	,,	,,	5	,,	,,
One failure to transmit			,,	8	,,	,,
One failure to transmit			,,	3	,,	,,

(A) Controls with no white-flies or any other insects put on the plants (February to June, 1930). Fourteen experiments on 19 plants ; none of which developed the disease.

(B) Controls with large numbers of white-flies known not to have bred or fed on a crinkly plant. Five experiments on 5 plants ; none of which developed the disease.

As the water-culture method of growing plants is somewhat laborious (though far more successful than had been anticipated) and as it had fulfilled its object of disproving the suggestion that leaf-curl might be a deficiency disease, all the subsequent experiments detailed in this paper were made on plants growing in soil in 4-gallon petrol tins. Except for a number of experiments to ascertain whether lack of drainage had any influence on the appearance of the disease, drainage was secured by cutting holes in the bottom of the tin and covering the bottom with a layer of broken brick. The seeds were covered with a lamp-glass as soon as sown ; this was replaced when the plants were a few inches high by a cage consisting of a wooden frame about 14 cm. square by 50 cms. in height, the top and three sides of which were covered with fine organdie muslin and the fourth side with glass. The glass side was turned to the north, except during the months of May to August, when, as the sun is then in the north at mid-day, it was placed facing south.

A certain number of similar but larger cages were used for experiments which it was desired to keep going for several months.

As a rule several seeds were sown, but the plants were thinned out to one or two per tin before white-flies were inserted into the cages.

The white-flies used for transmitting the virus were either collected from Sakel cotton growing in a field where the percentage of crinkly plants was high (in which case it was necessary to filter out other insects inadvertently collected, by causing the white-flies to pass through a wire gauze screen of the smallest possible mesh), or, more usually, were those bred in captivity on plants which had already been infected.

Uninfective white-flies, as used in the control experiments and in many of the experiments subsequently described in this paper, were obtained either by collecting the insects from a cotton field, and breeding them for a generation in cages on lubia (*Dolichos lablab*) or by collecting them from a lubia field, and breeding them for a generation on either lubia or cotton in cages.

White-flies collected straight from lubia in the field could not with certainty be guaranteed uninfective, owing to the presence of numerous " ratoon " cotton plants (practically all of which are infected with leaf-curl) in almost every field of lubia.

Experiment No. II.

Plants grown in soil. White-flies used had been bred on crinkly Sakel plants, and were left on the plants to be infected.

(*a*) More than 10 white-flies (usually about 50) transferred to each plant; experiments carried out April to July, 1930.

Forty-one experiments on 49 plants, resulting in 34 successful transmissions on 42 plants, and 7 failures on 7 plants. (On three of the plants which failed to develop symptoms only between 10 and 15 white-flies were used.)

(A) Controls with large numbers of white-flies known not to have bred or fed on a crinkly plant; experiments carried out April to July, 1930. Ten experiments on 16 plants, none of which developed any symptoms.

(*b*) More than 10 white-flies (usually 50–100 or more) transferred to each plant; experiments carried out October, 1930, to February, 1931.

Forty-three experiments on 79 plants, 76 of which developed crinkle. Of the three failures, one was thought not to be a true Sakel type, the other two (both in one tin) were 9 weeks old when the white-flies were placed on them, and for some reason were making very slow growth. Possibly they were pot-bound, though other plants have maintained vigorous growth for a much longer time.

(B) Controls with large numbers of white-flies known not to have bred or fed on an infected plant; experiments carried out October, 1930, to February, 1931. Three experiments on 8 plants, none of which developed any symptoms.

Thus the total number of straightforward transmissions from crinkly Sakel to Sakel, using at least ten and usually fifty or more white-flies per plant, which have been attempted, is 168, of which 157 have been successful and only 11, or under 7 per cent., have resulted in failure.

In addition to the transmission experiments on plants growing in water-cultures described above, the following attempts were made to transmit the disease to Sakel cotton growing in soil in petrol tins, using small numbers of white-flies.

One successful transmission		with	6	white-flies.	
One	,,	,,	,,	5	,, ,,
Three	,,	,,	,,	1	,, ,,
One failure to transmit			,,	3	,, ,,
Eleven failures	,,		,,	1	,, ,,

It should be mentioned that in the experiments with a single white-fly, if the insect was not observed to be alive on the day following that on which it was placed on the plant—which was the case a considerable number of times—the plant was destroyed and the experiment not recorded in the results above.

If transmission of the disease is obtained with a single white-fly, the resulting symptoms of crinkle are liable to be just as severe as if a large number is used to transmit the infection.

Six transmission experiments with Aphids (*Aphis gossypii*, Glover), which in any case are extremely rare on cotton under normal conditions in the Gezira, all gave negative results ; as did a number of further experiments—other than those detailed in the writer's previous paper[7]—with *Empoasca facialis*, Jac. (JASSIDAE).

It is therefore concluded that *Bemisia gossypiperda*, Misra & Lamba, is not only an extremely efficient transmitter of the virus of leaf-curl, but is in all reasonable probability the only vector of the disease.

Shambat Experimental Farm is situated a few miles north of Khartoum and is, therefore, some 50 miles to the north of the present northern limit of the irrigated area of the Gezira.

It has been stated that on this farm leaf-curl spreads very much more irregularly than it does in the Gezira. However, nothing is known with certainty about the seasonal life-history and variation in abundance of white-flies there.

It has also been stated that although infected white-flies from the Gezira transmitted the disease readily when brought to Shambat, local Shambat white-flies failed to do so. In view of this statement and the contradictory one made by the same worker that " Feeding experiments with White Fly brought (to Shambat) from diseased plants in the Gezira were consistently negative " ([10], p. 78), it was thought advisable that an entomologist should ascertain whether there was in fact any difference between white-flies from Shambat and from the Gezira as regards their ability to transmit the virus of leaf-curl.

The following experiments were therefore undertaken by Mr. W. Ruttledge, Assistant Entomologist, at Khartoum.

The plants to be infected were grown in soil in tins and protected at first by lamp-glasses and then by cages, as in the author's own experiments.

(*a*) Transmission experiments to healthy Sakel plants using white-flies collected at Shambat and fed on Sakel plants that had become crinkly at Shambat ; 50 white-flies put on the two plants in each tin, on 5.ii.1931.

No.	Date plants first showed symptoms	Incubation period (days)
1	22.ii.31 (both)	17 (both)
2	16.ii.31 22.ii.31	11 17
3	22.ii.31 (both)	17 (both)
4	23.ii.31 (both)	18 (both)
5	22.ii.31 (both)	17 (both)
6	25.ii.31 28.iii.31	20 51*
7	22.ii.31 (both)	17 (both)
8	23.ii.31 (both)	18 (both)
9	22.ii.31 No symptoms	17 failure

* It is possible that this plant escaped infection by the white-flies originally put on, but later became infected from those which had bred on the other plant.

(A) As a control to the foregoing, white-flies were collected in the Gezira, fed upon Sakel plants that had become crinkly in the Gezira, and sent to Khartoum, where the following experiments were done with them.

No.	No. of white-flies put in each cage (containing two plants)	Date plants first showed symptoms	Incubation period (days)
1	50	15.iii.31 No symptoms	21 failure
2	50	8.iii.31 11.iii.31	14 17
3	50	9.iii.31 (both)	15 (both)
4	40	14 iii.31 (both)	20 (both)
5	30	8.iii.31 10 iii.31	14 16
6	50	14.iii.31 15.iii.31	18 19
7	50	12.iii.31 17.iii.31	16 21
8	25	26.ii.31 14.iii.31	14 30
9	25	8 iii.31 (both)	24 (both)
10	25	1.iii.31 (both)	17 (both)
11	25	1.iii 31 No symptoms	17 failure
12	25	1.iii.31 8.iii.31	17 24

It is therefore seen that under the same conditions at Khartoum, Shambat white-flies fed upon Shambat crinkly Sakel plants transmitted the disease 17 times out of 18, and Gezira white-flies fed upon Gezira crinkly plants 22 times out of 24. The foregoing experiments, carefully carried out by an entomologist fully qualified to undertake such work, are amply sufficient to disprove the alleged difference between the infective powers of Shambat and Gezira white-flies.

4. Evidence that Virus of Leaf-curl is not transmissible through Seed.

(*a*) The total number of Sakel plants which have been grown under controlled conditions either in water cultures, or in pots or petrol tins, or in the field, and on which either no insects at all have been placed, or insects other than white-flies, or white-flies known not to have bred or fed on an infected plant, is over 300. Not one of these has ever developed the slightest trace of any symptoms. By itself, however, this evidence is of small value, as the extent of the disease on the plants which produced the seed used in most of these experiments is not known with certainty.

(*b*) From an area of Sakel cotton sown on 1.xi.1928, seed was obtained during April 1929 (1) from those plants which showed the severest symptoms of crinkle ; (2) from such plants as were still unaffected.

These seeds were sown in two plots side by side at the end of August 1929. The resulting plants were not protected in any way, but observations on about 300 plants in each plot showed that leaf-curl did not appear on either plot until October, and then developed equally and simultaneously on both.

(*c*) A plot of over 1,000 Sakel cotton plants was sown on 15.iv.1930; at that time practically no white-flies could be observed on the Gezira Research Farm, and none was ever seen on any of the plants in this plot. None of these plants developed any symptoms.

(*d*) Two adjacent cotton numbers (*i.e.*, each of about 70 feddans) in Tebub Block, one of which had been sown with Egyptian seed and can, therefore, be presumed to have come entirely from uninfected plants, and one with Gezira seed, which would certainly have been from plants with a high percentage of leaf-curl, both contracted the disease equally and simultaneously, so far as could be ascertained from somewhat rapid inspections—time did not permit of accurate counts being made on these numbers.

(*e*) If infected white-flies are placed on a cotton seedling as soon as it has appeared above the ground, even before the cotyledons have unfolded, the symptoms of crinkle will first appear sometimes on the first true leaf and very frequently on the second leaf. A Sakel plant is therefore capable of showing the symptoms as soon as it has produced its first leaf.

Now cotton is normally sown in the Gezira during the month of August, but the first appearance of crinkle in the field has never been noticed until the last few days of September, *i.e.*, some 40–50 days from the date of sowing. The reason for this is undoubtedly that during August and early September there are very few white-flies about, and those that do appear in August are probably not infected with the virus (this question is more fully discussed in Section 34). If the virus were ever carried in the seed, some of the seedling plants would be certain to show the symptoms as soon as they are capable of doing so, *i.e.*, by early September.

Additional weight is given to this argument by the fact that if cotton is sown in the field in October or November, when infected white-flies are abundant, the first symptoms of crinkle appear between 20 and 30 days from the date of sowing (*vide* 7, Table III, p. 131).

Any one of the foregoing five arguments, except perhaps the last, would by itself be inconclusive, but taking all five together, it is believed that the arguments against the transmission of the virus of leaf-curl though the seed of Sakel cotton are as conclusive as arguments based on negative evidence ever can be.

The only reason why seed transmission has ever been suggested seems to be the supposed difficulty of otherwise accounting for the appearance of the disease in the isolated cotton areas of Kassala and Tokar. Yet white-flies have penetrated to those areas, and if uninfected white-flies can do so, why not infected ones?

If it is still desired to postulate seed transmission, it seems necessary to assume, in view of the evidence detailed in (*e*) above, that a very small percentage of seeds produced plants which are carriers of the virus, but themselves show no symptoms. Although with virus diseases all things appear possible, this seems an unnecessarily far-fetched explanation for a probably non-existent phenomenon.

5. Evidence that Virus of Leaf-curl cannot be transmitted through Soil.

Certain virus diseases of plants can apparently be transmitted by the soil, *e.g.*, that of tobacco mosaic, according to McKinney[11] and Moutia.[13] With most virus diseases, however, there is either no evidence in favour of such a method of transmission, or a considerable amount of circumstantial evidence against it. With the

virus of cotton leaf-curl there is certainly no positive evidence in favour of soil transmission, and the following facts, though scarcely conclusive, can be quoted against it.

Thirty Sakel plants, used as controls in various experiments, were deliberately planted in 13 different tins, in the same soil as that in which crinkly Sakel plants had been growing, and immediately after their removal. None of these developed any symptoms of the disease. Similarly 16 plants of Watts Long Staple cotton, also used as controls in experiments to be subsequently described, were grown in six tins in the same soil as, and immediately after the removal of, crinkly Sakel plants. None of these developed the mosaic type of infection described in Section 23, or any other symptoms.

6. Incubation Period of Virus in Sakel Cotton.

Although if all methods of transmitting the disease to healthy Sakel by means of white-flies from crinkly Sakel are included, over 200 successful transmissions have been performed, and the incubation period of each recorded, little can be said with certainty as to the causes responsible for the very considerable variations noticed.

The following table gives the results of all transmissions from Sakel to Sakel except (i) early experiments done before the first definite symptoms were correctly diagnosed; (ii) a small number in which (owing to absence, etc.) the error in recording the first appearance of the symptoms may have been more than two days; (iii) those in which no symptoms appeared until after the plant was topped (for these see (4) below).

Incubation period (days)	Number of observed examples	Approximate percentage in each category
8–10	25	13
11–13	44	23
14–16	46	24
17–19	40	21
20–22	16	8
23–25	12	6
26–28	4	2
29–31	3	1·5
32–34	3	1·5

Certain possible factors which might influence the period of incubation may be discussed.

(1) *Temperature.*

All the very short period incubations, *i.e.*, of 8, 9 or 10 days, were recorded in comparatively warm weather, *i.e.*, a maximum averaging about 40° C. or more, and a minimum of not less than about 20° C.

The converse, however, is not the case; many periods of 20 days or more were recorded in equally warm weather, while during the coolest weather experienced at Wad Medani during the rather exceptionally warm winter of 1930–31, several instances occurred of incubation periods of 14–16 days.

(2) *Soil Temperature.*

It was thought that the temperature of the soil might have some effect on the incubation period of the virus in the plant, but the results of the following experiment seem to indicate that this is at any rate not important.

Experiment No. III.

Six tins were sown on 4.i.1931. All were thinned to one plant on 11.i.31, *i.e.*, as soon as the cotyledons had fully unfolded, the seedlings left being as nearly as could be judged exactly equal in appearance. On this date tins Nos. 1 and 2 were painted black, Nos. 3 and 4 painted white, and Nos. 5 and 6 covered with several thicknesses of cheese cloth which was kept wet. Approximately 50 white-flies from crinkly Sakel plants (all from the same source) were placed on each plant on 11.i.31. The soil temperatures at 5 centimetres were recorded, and though they must be regarded as approximate only, are quite significantly different; moreover the plants in the two tins with a low soil temperature grew appreciably slower than those in the other four.

No.	Average soil temperature at 5 cm.			Incubation period (days)
	at 7.0 a.m.	at 2.0 p.m.	at 5.0 p.m.	
1 2	16·5° C.	38° C.	37° C.	11 11
3 4	15·0° C.	35° C.	33° C.	20 19
5 6	11·0° C.	27° C.	23° C.	14 14

It must be stated that nos. 1, 2, 5 and 6 all developed the first symptoms on the second leaf, while nos. 3 and 4 first became crinkly on the third leaf.

Experiment No. IV.

A repetition of the previous experiment was then carried out, with the addition that the plants in alternate tins were shaded from the direct rays of the sun. The tins themselves were not shaded, and the soil temperatures were practically the same as those recorded in Experiment no. III. The seeds were sown on 2.ii.31 and thinned to two equal-looking seedlings on 9.ii.31 (except in no. 4 where only one seedling comparable with the others was available). About 100 white-flies all from the same crinkly Sakel plant were put on the plants in each tin on 9.ii.31.

No.	Incubation period (days)
1 (Tin painted black, plants shaded)	16 16
2 (Tin painted black, plants unshaded)	12 13
3 (Tin painted white, plants shaded)	11 12
4 (Tin painted white, plants unshaded)	11
5 (Tin kept wet, plants shaded)	16 18
6 (Tin kept wet, plants unshaded)	11 14

All these plants developed the first symptoms on the second leaf except one plant in no. 3, on which it appeared on the first leaf.

On both the plants in no. 3, however, the symptoms, although first manifested as early as on any of the others, did not spread until 16 days had elapsed from the date of infection. It therefore seems that shading, especially in conjunction with a low soil temperature, may have some effect in retarding the incubation period, or if not, then in retarding the rapid spread of the symptoms.

(3) *The age of the plant when infected white-flies are put on it.*

The majority of the plants used in all the transmission experiments have been quite young at the time infection was induced, this being essential in order to save time and to keep within reasonable bounds the number of tins to be looked after at any one time.

Several, however, have been infected when a month old, a few at six weeks and three when over five months old, and no correlation can be found between the incubation period in such older plants and that in seedlings which are infected the moment they appear above the soil, before the cotyledons are fully expanded.

The following experiment also indicates that the age of the plant has no connection with the period of incubation of the disease.

Experiment No. V.

Seeds were sown in seven tins at interval of three days. Two plants were left in each tin. On 17.ii.31 all were infected by means of approximately equal numbers of white-flies from crinkly Sakel plants. The weather during the ensuing ten days was abnormally warm for the time of year, which may account for the very short incubation period in most of the plants.

No.	Age of plants when infected white-flies put on (days)	Incubation period (days)	Number of leaf on which symptoms first appeared
1	24	8 8	5th 5th
2	21	8 8	4th 5th
3	18	8 8	3rd 3rd
4	15	8 11	3rd 3rd
5	12	8 13	2nd 3rd
6	9	8 9	2nd 2nd
7	6	8 8	2nd 2nd

Although it is seen that at least one plant in each tin developed the symptoms in 8 days, which is equal to the shortest period yet recorded, the crinkle tended to spread more rapidly on those plants—nos. 5, 6 and 7—which had been infected young.

It can also be stated from observations on other experiments that if infected white-flies are put on a plant still in the cotyledon stage, the symptoms as a rule, but not always, become very severe ; if infection is deferred until the plant is older, the symptoms may sometimes become just as severe as in the former case, but considerably less often.

(4) *Occasional failure of the symptoms to develop until brought on by mutilation of the plant.*

The following few cases have been observed in which no symptoms had appeared after a lapse of time from the date of infection considerably longer than the normal incubation period, as recorded on other similar plants at the same time.

Date when infected white-flies were put on plant.	Number of days from date of infection when no crinkle was b-served, and plant was topped.	Number of days after topping when symptoms first noticed.	Total incubation period (days).
29.v.30	21	10	31
1.vi.30	22	10	32
1.vi.30	23	11	34
30.xi.30	35	14	49
30.xi.30	32	18	50

It cannot of course be said with certainty that any of these plants would not have developed the symptoms of crinkle, after an incubation period longer than normal, even if they had not been topped.

7. Factors influencing the Severity of the Disease.

It has been stated above (Section **6**, 3) that plants infected very young tend to become very badly crinkled, but that the converse is not the case. It is also known that a reasonably rapid and healthy growth of the plant is an essential condition for the manifestation of the severer forms of crinkle. Occasional plants have been noticed among those grown under controlled conditions in which growth has been slow and the plant weak—usually owing to too many white-flies having been put on it, and the resulting direct damage thereby. Such plants have never developed severe crinkle.

Similarly numerous plants have been noticed in the field which from some cause or other have failed to grow normally ; these seldom have the symptoms as severely developed as otherwise well-growing plants.

Apart from these two factors, the second of which is paralleled in most if not all other virus diseases, no reasons can be assigned for the commonly observed fact that of two plants, apparently in every way equal and perhaps growing in the same tin, one may develop crinkle in its worst form, while the other remains comparatively mildly affected.

The following assertions can however be made with confidence :—

(1) White-flies from a comparatively mildly affected Sakel plant can infect other Sakel plants with the severest form of the disease, while the converse is also true ; it would thus appear that there is no cause to suppose the existence of different strains of the virus differing in intensity, and that the relative severity of the symptoms

is therefore more likely to be dependent on some unknown factor in the plant than on the virus or the transmitting agent.

(2) There is no evidence that passage of the virus through a number of Sakel plants causes either attenuation or intensification of the symptoms.

The virus has been transferred through seven successive series of plants, and the last to be infected (in March 1931) showed the symptoms to the same degree as the first (in February 1930). The fourth plant in this series, it may be of interest to note, was one of those infected by means of a single white-fly.

Passing the virus through Til (*Hibiscus cannabinus*, L.) and back to Sakel cotton, in no way alters the symptoms on the latter.

(3) Similarly, there is no evidence that white-flies which have been breeding generation after generation on crinkly Sakel, either lose the power to transmit the disease readily or transmit it in an attenuated form.

(4) White-flies can pick up the virus and transmit it to healthy plants as readily from a plant which has been infected a long time (at any rate up to five months) as they can from a plant which has only recently become infected, and the resulting symptoms are in no way distinguishable.

8. Recovery and Partial Recovery of Infected Sakel Plants.

Complete recovery from the disease has only been observed on plants growing under controlled conditions in the following few instances.

(1) Seed sown 12.vi.30. Plant infected by white-flies on 23.vi.30. Crinkle observed on 10.vii.30. On 19.vii.30 it was still slight, and there was no increase by 29.vii.30, the new growth being then apparently normal and remaining so until 14.ix.30, when the plant was destroyed.

(2) Seed sown 18.vi.30. Plant infected by white-flies on 25.vi.30. Crinkle observed on 12.vii.30. New growth normal on 29.vii.30, remaining so until the plant was destroyed on 14.ix.30. (Neither of these two plants was topped to see if this would bring back the symptoms.)

(3) Seed sown on 29.x.30. Plant infected by white-flies on 9.xi.30. Definite but localised crinkle on one leaf only noticed on 7.xii.30 (would probably have been apparent some days earlier). No further spread by 3.i.31, when the plant was topped, and no symptoms on the abundant and vigorous growth produced by 22.ii.31, when the plant was removed.

This is perhaps the only definite instance of complete recovery, which is further substantiated by the fact that white-flies bred on this plant were transferred to two healthy Sakel plants, neither of which developed any symptoms.

Only one other case of apparently complete recovery under controlled conditions has been observed, but this was on a plant grown from seed specially selected for resistance, and is mentioned in Section **9** (2, *b*).

One definite instance of apparently complete recovery, but in which the disease was brought on again after the plant was topped, is worth recording. Seed sown 18.x.30. Plant infected 31.x.30. Very definite but localised crinkle on one leaf noticed on 26.xi.30. All new leaves normal on 18.xii.30, when the plant was topped. Mild crinkle appeared all over the new growth which had been produced by 29.xii.30. The original small crinkly area remained the same.

Partial recovery, that is to say cases in which a plant that has been severely affected subsequently produces leaves showing the symptoms to a much lesser extent, has been observed several times on plants growing under controlled conditions, and quite often in the field.

No reason can at present be suggested why, of two plants growing perhaps in the same tin, or side by side in a cotton field, one should show a distinct tendency to recover, while the other should remain badly crinkled throughout its life.

9. Notes on Resistant Strains of Sakel Cotton.

In any field of cotton in the Gezira in which infection by leaf-curl is widespread, a small proportion—usually less than 5 per cent.—of plants will be found which show no symptoms of the disease. Many of these are more or less obvious " rogues," or at least off-types, but some are apparently pure-type Sakel plants.

Mr. A. R. Lambert (Inspector of Botanical Work, Agricultural Department) has collected seed from a number of such plants, and tested them for resistance to leaf-curl in the field. Doubtless a full account of his tests will be published by him, but the following brief notes on three of his selected strains, a few seeds of which he kindly gave to the writer for testing under controlled conditions, may be of interest.*

(1) Strain 29/18.

(*a*) Sown in field on 12.viii.30. Examined on 21.i.31 ; 26 plants, of which 15 sound and 11 infected ; of these 11, 8 had traces only, and 3 mild crinkle. Examined on 12.iii.31 ; 25 plants, of which 18 sound and 7 infected ; of these 7, 3 had traces only, 3 mild and one moderate crinkle.

Five plants had definitely recovered, while only one had become (slightly) worse, and one which had been sound at the first inspection now showed slight traces.

(*b*) Four plants tested under cages, sown 27.xi.30. Infective white-flies inserted on 6.xii.30. Two plants developed moderate crinkle (incubation period 23 days for both) and two remained perfectly sound.

(2) Strain 29/20.

(*a*) Sown in field on 12.viii.30. Examined on 21.i.31 ; 27 plants, of which 24 sound and 3 infected ; of these 3, 2 had traces only and 1 mild crinkle. Examined on 12.iii.31 ; 27 plants, of which 25 sound and 2 infected (one with traces only, one mild).

One plant had definitely recovered, and none had become worse.

(*b*) Five plants tested under cages ; sown 27.xi.30. Infective white-flies inserted on 6.xii.30. All five developed crinkle, but one only developed slight traces 17 days after being topped and 48 days after being infected ; one developed mild crinkle after 19 days, but a month later had completely recovered ; one developed rather bad crinkle after 17 days but later recovered to a marked extent but not completely ; the other two remained rather badly affected.

(3) Strain 29/27.

(*a*) Sown in field on 12.viii.30. Examined on 21.i.31 ; 27 plants of which 14 sound and 13 infected ; of these 13, 4 had traces only, 5 mild and 4 moderate crinkle

* *Note by Mr. A. R. Lambert.* The above strains can be classed as of Sakel type. There is actually a (comparatively slight) deviation from modal Sakel characters in some respect in each case, but not more than occurs frequently among Sakel. They were selected in a plot of " Massey's Domains Sakel "—a strain originating from Egyptian Domains Sakel, and maintained at a good standard of purity each year by the Plant Breeder, Sudan Government.

Unselfed seed only was obtained and some at least of the susceptibility to the leaf-curl can be ascribed to crossing. Generally the families show a comparatively good purity to family type.

Strains LCR/29/18 and LCR/29/27 were entirely free from leaf-curl in the 1929–30 season, but LCR/29/20 developed the symptoms at the end of the season (1929–30) although not badly. It is an unexpected result that the latter now appears to be the most resistant of the three.

Several other selections showed a high degree of resistance to the disease, but the above three are probably the most promising on general grounds.

Examined on 12.iii.31 ; 27 plants, of which 14 sound and 13 infected (3 with traces only, 4 with mild and 6 with moderate crinkle).

Thus none had recovered and two had become slightly worse.

(*b*) Seven plants tested under cages. Sown 27.xi.30. Infective white-flies inserted on 6.xii.30. Six developed crinkle (three rather bad, two moderate and one mild) and one remained entirely sound.

(4) Control ; ordinary bulk Sakel.

(*a*) Sown in the field on 12.viii.30 (in rows adjacent to the above three strains). Examined on 21.i.31 ; 99 plants of which 2 sound and 97 crinkly ; of these 97, none had traces only, 13 had mild, 82 moderate, and 2 severe crinkle.

(*b*) Five plants tested under cages. Sown 27.xi.30. Infective white-flies inserted on 6.xii.30. All 5 developed crinkle, 4 becoming bad and one remaining fairly mild.

It is thus seen that all the three selected strains, particularly the first two, showed a very considerable degree of resistance in the field. This was certainly not due to their not having been fed upon by white-flies, since just as many larvae seemed to be on them as on the adjacent ordinary Sakel. It is thought probable that the apparent resistance of these plants was due not to their entirely failing to contract the disease when infected, but to their tendency to show only slight symptoms and to recover from these to a greater extent and more frequently than ordinary bulk Sakel.

Owing to pressure of other experiments, it was not possible to keep the plants grown under cages for more than about two months, but it is very likely that if they had been kept, many of the others would have shown partial or complete recovery.

10. Parts of an Infected Sakel Plant which show no Symptoms are viruliferous.

For this experiment, Sakel plants which had been grown in tins and previously infected were topped well below all visible signs of the disease. Furthermore, all secondary buds, which might possibly have produced minute crinkly leaves during the following two days, were destroyed.

Uninfected white-flies were then placed on these plants and left for 48 hours ; they were then transferred to young healthy Sakel plants as follows :—

Experiment No. VI.

No.	Number of plants in tins	Age of plants when infected (days)	Date infected white-flies put on plant	Incubation period (days)	Remarks
1	1	20	6.i.31	23	A badly growing plant ; it may have developed the first signs of crinkle some days before recorded.
2	1	8	26.i.31	12	Subsequently developed very severe crinkle.
3	2	9	31.i.31	11 13	Ditto.

Although transmission has only been attempted in this way from three Sakel plants from which all diseased growth had been removed, to the above four healthy plants, it was successful in all cases, and it is therefore concluded that white-flies can readily pick up the virus from the apparently healthy parts of diseased plants.

11. Is an Infected Sakel Plant viruliferous before it develops visible Symptoms ?

Experiment No. VII.

(*a*) Infected white-flies were put on a plant on 29.v.30 ; this plant showed no symptoms by 19.vi.30, when it was topped. On 29.vi.30, that is to say 31 days after the white-flies were put on it and 10 days after being topped, it developed crinkle, which subsequently became severe.

On 19.vi.30 a large number of white-flies, the offspring of the original ones put on, were removed to a healthy Sakel plant 20 days old ; this plant developed moderately severe crinkle.

It was not however definitely recorded whether all the original white-flies had died before the second generation emerged, and though it is very unlikely that any of them had survived for 21 days, and thus got transferred with their offspring, if such were the case it would vitiate the experiment, which must therefore be considered inconclusive.

(*b*) Infected white-flies were put on two 30-day old Sakel plants in one tin on 17.xi.30. All these white-flies were removed after 48 hours. One of these plants developed crinkle after 19 days, the other after 30 days.

Before the symptoms appeared five consecutive lots of uninfected white-flies were put on these plants for not less than 48 hours, after which they were transferred to healthy Sakel plants ; the last lot were enclosed on 1.xii.30, and transferred on 4.xii.30, *i.e.*, only two days before the first plant developed crinkle. None of the plants to which they were transferred developed the disease.

It is obvious that negative evidence such as this is of little value, but in view of the possible uncertainty attaching to experiment (*a*) it cannot be taken for granted that a plant is viruliferous before it shows definite signs of the disease.

12. Adult White-flies which in their Larval Stage, but not as Adults, have fed on infected Sakel Plants are efficient Transmitters of the Virus.

As it is impossible to remove the larvae or pupae of white-flies from the leaves to which they are attached, the method of determining this point was to pick crinkly Sakel leaves on which were large numbers of larvae and pupae, and to transfer the adults as they emerged to healthy Sakel plants grown under cover.

Experiment No. VIII.

(*a*) Crinkly Sakel leaves collected about noon of 30.x.30. At noon on 31.x.30 all the white-flies which had emerged (about 30) transferred to a healthy seedling 13 days old. This plant developed crinkle on 26.xi.30, *i.e.*, after 26 days. It remained mild and localised until 18.xii.30, when the plant was topped ; by 29.xii.30 the new growth showed symptoms all over.

(*b*) Between 20 and 30 white-flies which emerged from the leaves mentioned in experiment (*a*) between noon 31.x.30 and noon 1.xi.30 were transferred to two healthy seedlings 14 days old in one tin. Crinkle appeared on one plant after 15 days and on the other after 17 days. Both plants subsequently developed very severe crinkle.

(*c*) Between 20 and 25 white-flies exactly similar to those used in experiment (*b*) transferred to two healthy plants (14 days old) in one tin at noon on 1.xi.30.

One plant developed symptoms (which subsequently became moderately severe) after 33 days, the other never became crinkly. No reason can be given for this failure.

(*d*) About 50 white-flies exactly similar to those used in experiments (*b*) and (*c*) transferred to two healthy plants (14 days old) in one tin at noon on 1.xi.30.

One plant developed the disease after 17 days, the other after 18 days Both subsequently became moderately severely crinkled.

(*e*) Crinkly Sakel leaves picked in the early morning of 4.xi.30. All white-flies which emerged before 1.0 p.m. on 5.xi.30 were rejected. On the morning of 6.xi.30, 10–15 white-flies were transferred to one healthy seedling 18 days old, which developed crinkle after 18 days, the symptoms subsequently becoming rather severe.

(*f*) About 30 white-flies which emerged between 8.xi.30 and 9.xi.30 from the same leaves (picked on 4.xi.30) as those mentioned in experiment (*e*) were transferred on 9.xi.30 to one healthy seedling 11 days old. This plant after 28 days showed definite but localised crinkle, which never spread, nor did the symptoms re-appear on the new growth after the plant was topped on 3.i.31.

(This is one of the few recorded cases of apparently complete recovery, *vide* Section **8** (3).)

(*g*) About 30 white-flies which emerged between 2 p.m., 10.xi.30, and 1 p.m., 11.xi.30 from crinkly leaves picked in the early morning of 9.xi.30, were transferred to a healthy plant 24 days old. This plant developed crinkle (which subsequently became severe) after 21 days.

(*h*) About 15 white-flies which emerged between 14.xi.30 and 15.xi.30 from the same leaves as those mentioned in experiment (*g*) were transferred to a healthy seedling 6 days old. This plant never developed any traces of crinkle even on new growth after it had been topped.

The white-flies (which were the last to emerge from these leaves picked 6 days before) were apparently feeble and did not live long or breed on the plant to which they were transferred, and it is thought that this may be the cause of the failure.

Some doubt may be entertained as to the validity of the first experiment (*a*), as the leaves were still flaccid when the white-flies emerging from them were transferred, but in all the other cases those white-flies which emerged before the leaves were dry were rejected, and it is not thought possible that they could feed on a dry and brittle leaf.

13. How long White-flies which have once picked up the Virus remain capable of transmitting it.

As a preliminary it may be stated that adult white-flies, deprived of food and water, remain alive in the normal dry atmosphere of the Sudan only for a few hours. If given water (on wet filter paper) but no plant to feed on, about one half will usually survive for 24 hours, but very few for more than 36 hours. When enclosed on any plant on which they can feed, a few will usually be alive after a fortnight or more, but the majority will be dead after several days.

The following experiments have been made to ascertain how long white-flies can retain the infective principle.

Experiment No. IX.

(*a*) White-flies from crinkly Sakel transferred to Lubia (*Dolichos lablab*) and thence to healthy Sakel plants

No.	Time kept on Lubia	Date transferred to healthy Sakel	Incubation period
1	24 hours	22.xii.30	16 days (one plant)
2	48 hours	23.xii.30	18 days (two plants)
3	72 hours	24.xii.30	Failed (two plants)
4	72 hours	27.i.31	14 days (two plants)

No reason can be assigned to the failure of no. 3, especially since an exact repetition (no. 4) resulted in successful transmission to both plants.

(*b*) White-flies from crinkly Sakel transferred to healthy Sakel plants (which subsequently became crinkly) and thence to other Sakel plants.

No.	Time kept on healthy Sakel	Date transferred to other healthy Sakel	Incubation period
1	48 hours	19.xi.30	19 days, 20 days (two plants)
2	7 days	16.ii.30	14 days, 15 days, 17 days (three plants)

(*c*) White-flies from crinkly Sakel kept without food, but with access to a wet filter-paper, and thence transferred to healthy Sakel.

Time kept without food	Date transferred to healthy Sakel	Incubation period
24 hours	24.xii.30	27 days (probably actually a few days less) on one plant; the other plant failed to develop symptoms but did not appear to be a pure-type Sakel plant.

No signs of attenuation of the virus were observed in any of the above experiments—in fact, both of the plants in (*a*) 4, and the one in (*c*), developed a very severe form of crinkle.

These experiments indicate that white-flies which have picked up the virus are quite likely to remain capable of transmitting it throughout their life.

14. Minimum Time in which uninfected Adult White-flies can pick up Virus from diseased Sakel.

It has been shown in Section 12, that in order to becàme capable of transmitting the virus it is not necessary for white-flies to have fed on a crinkly plant as adults, provided that their larvae have done so. The converse is also true; adult white-flies

can pick up the virus by feeding for a sufficient time on crinkly cotton even if as larvae they have lived on healthy cotton or on some host plant such as Lubia which does not either show symptoms of or contain the virus.

The following experiments were undertaken to ascertain the minimum time necessary for white-flies to feed on a crinkly Sakel plant, to enable them to transmit the disease to healthy Sakel.

Experiment No. X.

Large numbers of uninfected white-flies were enclosed for the time stated on crinkly Sakel plants (from which all other adult white-flies and all pupae and large larvae, had been carefully removed) and then transferred to healthy Sakel, on which they were left.

No.	Time kept on crinkly Sakel	Date transferred to healthy Sakel	Number of plants	Incubation period
1	7 days	4.xi.30	2	10 and 16 days.
2	5 days	6.xi.30	1	21 days
3	3 days	29.vi.30	1	13 days.
4	2 days	23.vi.30	2	12 and 13 days.
5	22 hours	10.xi.30	2	16 and 22 days.
6	18 hours	21.xii.30	2	13 and 15 days.
7	14 hours (*a*)	6.i.31	1	17 days
8	9¾ hours	17.i.31	2	15 and 16 days.
9	6 hours	25.i.31	3(*b*)	12 days (all).
10	5½ hours	9.ii.31	2	17 and 20 days.
11	4½ hours	7.ii.31	2	11 and 19 days.
12	3⅓ hours	20.xii.30	2	No transmission.
13	3⅓ hours	25.ii.31	3	16 days (two plants). No transmission (one plant).

(*a*) From 5.30 p.m. to 7.30 a.m., *i.e.*, mainly during the night. In the remaining experiments (nos. 8–13) the time was entirely during daylight.

(*b*) These three plants (as well as several of the others) developed the severest symptoms of crinkle; one of them had the longest foliar outgrowth (over 20 mm. in length) which has been observed. This is mentioned to show that restriction of the time in which the white-flies pick up the virus does not cause it to be transmitted in an attenuated form.

It would therefore appear that white-flies are capable of picking up the virus in just over 3 hours, though perhaps not with the same regularity as when a longer time is available. Further experiments are required with times of 3 hours and less.

15. Minimum Time necessary for infected White-flies to transmit Disease to healthy Sakel.

Smith,[20] working on the transmission of potato virus diseases by *Myzus persicae*, Sulz., found that "Aphids from infected plants can transmit leaf-roll to potatoes in two hours, and Aphids can pick up the virus from an infected plant in 6 hours, but the whole process of infection of the Aphid and the healthy plant cannot be performed in 8 hours. There appears to be a minimum period of about 54 hours before the non-infective Aphid can become infective. This may mean that there is some relationship between the virus and its insect carrier, or it may merely be the time necessary for the virus to travel round the body of the insect and return through the salivary juices" (Rev. Appl. Ent., 1930, p. 519).

The following few experiments, though very inadequate, show that leaf-curl can be transmitted by infective white-flies in 30 minutes, and that the whole process of infection of the white-flies and of the healthy plant has been accomplished in 6½ hours.

Experiment No. XI.

No.	Time white-flies fed on crinkly plant	Date white-flies transferred to healthy plants	Time left on healthy plants	Number of plants	Remarks
1	(bred)	29.vi.30	½ hour	3	All crinkly after 18 days, possibly earlier.
2	(bred)	30.xi.30	½ hour	2	One developed crinkle after 18 days, the other never.
3	6 hours	14.ii.31	2 hours	2	One developed crinkle after 14 days, the other never.
4	6 hours	14.ii.31	½ hour	2	One developed crinkle after 11 days, the other never.
5	5½ hours	9.ii.31	2½ hours	2	Neither plant developed crinkle.

Many more experiments on these lines are, however, required before any conclusions can be drawn as to whether there is an obligatory period of incubation of the virus in the white-fly.

16. Virus not transmissible through Egg of White-fly.

Numerous experiments, the particulars of which are scarcely worth recording (most of those detailed in Experiment I, B ; II, A ; and II, B ; as well as many others) have shown that if white-flies from crinkly Sakel are transferred to Lubia, the following generation, bred entirely on Lubia, is incapable of transmitting the disease, which therefore cannot pass through the egg of the white-fly.

It is believed that this is in agreement with the results found for all other virus diseases of plants which are transmissible by insects.

A few (but by no means all) of the other common host plants of the white-fly have been substituted for Lubia with the same result.

However, the possibility that some of the other host-plants of the white-fly might be capable of "carrying" the virus in an invisible but transmissible form should not be lost sight of.

17. Transmission of Virus from Sakel Cotton to Bamia (*Hibiscus esculentus*).

The symptoms of the disease on Bamia are very similar to those on Sakel cotton, the net-vein enations are very conspicuous, but large cup-shaped outgrowths, such as are common on a badly infected Sakel plant, have not been noticed. There is scarcely any abnormal curling of the leaves unless a plant is very severely affected, when the leaves are small and thick and curled downwards more often than upwards.

The following transmission experiments have been made with white-flies from crinkly Sakel to Bamia.

Experiment No. XII (a).

Five Bamia plants grown in separate tins were infected on 17.v.30 by means of white-flies from crinkly Sakel plants. The Bamia plants had been sown on 13.v.30 and were thus small seedlings in the cotyledon stage.

One plant developed crinkle after 17 days and another after 20 days ; the remaining three failed to contract the disease. However, for some reason no white-flies survived for long on any of these plants, nor did the plants themselves grow as vigorously as the two which became infected. This may possibly explain the three failures.

Five similar Bamia plants on which known uninfected white-flies were placed all developed normally.

Experiment No. XII (b).

No.	Number of Bamia plants in tin	Age of plants when infected (days)	Date infected white-flies put on plants	Incubation period (days)	Remarks
1	2	9	6.xi.30	28* (both)	Both plants with fairly mild crinkle.
2	1	29	27.xi.30	21	Ordinary but not very severe crinkle.
3	2	29	27.xi.30	32* / —	One plant failed to develop crinkle.
4	2	29	27.xi.30	32* (both)	Crinkle remained rather mild on both plants.
5	2	17	23.xii.30	16 / 20	Crinkle became moderately severe on later growth.
6	2	17	23.xii.30	17 / 19	Crinkle became moderately severe on later growth.

It is thus seen that of 16 attempts to transmit the disease from Sakel to Bamia 12 have been successful, and that transmission is therefore readily obtainable, though perhaps with not quite the same regularity as from Sakel to Sakel.

18. Attempted Transmission from Bamia (*Hibiscus esculentus*) to Sakel Cotton.

Experiment No. XIII.

It will suffice to say that 11 separate experiments on 17 plants have all resulted in failure; in no case has the slightest trace of any symptom been observed on a Sakel plant after white-flies from crinkly Bamia have been put on it. The Sakel plants were all topped about a month after the attempted infection, in case the symptoms should be latent, but the new growth was in every instance perfectly normal. The white-flies used in 10 of the experiments were ones which had bred and fed on caged crinkly Bamia plants; in the remaining one they were uninfected white-flies which had been enclosed for 48 hours on a Bamia plant growing in the field, which showed the symptoms of curl as well as severe crinkle.

An indication that these Sakel plants, apparently unaffected by white-flies from crinkly Bamia, did not harbour the virus in an invisible but transmissible form (*cf.* Section **26**), is afforded by the experiments detailed in Section **27**, nos. 3 and 4.

While it is obvious that failure on 17 plants does not necessarily mean that the disease can never be transmitted from Bamia to Sakel, it is at least certain that, if possible at all, it is very much harder to secure than from Sakel to Bamia.

19. Transmission from Sakel Cotton to Til (*Hibiscus cannabinus*).

The symptoms of the disease on Til are extraordinarily conspicuous. The net-vein enations are very well marked, the veins being extremely thick and gnarled on the underside, though large foliar outgrowths do not seem to be produced. The leaves remain small and are distinctly curled upwards. When a plant has been

* The disease had very probably appeared some days before it was recorded.

infected for some few weeks the intercostal areas become yellowish, the veins remaining dark green, thus giving a mosaic appearance to the leaves. However, new growth produced by such a plant will at first only be crinkled and curled. To a certain extent, therefore, Til, when infected with leaf-curl by white-flies from crinkly Sakel, combines the features of crinkle, curl and mosaic.

A certain amount of Til has been planted on the Gezira Research Farm during the past two seasons, almost every plant of which became naturally infected ; it is not however grown in the rest of the Gezira area. Owing therefore to its relative unimportance, few experiments have been carried out with it, but these are sufficient to show that the virus is readily carried from Sakel to Til by white-flies.

Experiment No. XIV.

No.	Number of plants in tin	Age of plants when infected (days)	Date infected white-flies put on plants	Incubation period (days)	Remarks
1	3	7	11.xi.30	16 (two plants) 28 (one plant)	Symptoms became exceedingly severe on all plants.
2	1	13	17.xi.30	—	Failed to develop any symptoms, but for some reason this plant grew very badly and was almost dead before it was two months old.
3	3	13	17.xi.30	15 (two plants) 31 (one plant)	Symptoms became exceedingly severe on all plants.

Only one control experiment was carried out, using uninfected white-flies ; the plant grew entirely normally in every way.

20. Transmission from Til to Sakel Cotton.

Experiment No. XV.

No.	Number of plants in tin	Age of plants when infected (days)	Date infected white-flies put on plants	Incubation period (days)	Remarks
1	2	16	18.xii.30	13 (both plants)	Crinkle became severe.
2	1	20	22.xii.30	—	Failed—less than 15 white-flies were used, which did not breed on the plant.
3	2	14	5.ii.31	$\begin{cases}12\\13\end{cases}$	Crinkle became severe.
4	2	11	14.iii.31	11 (both plants)	Crinkle became severe.

In numbers 1 and 2 the white-flies used were the subsequent generation arising from those which had been put on the plants in Experiment XIV, 1 ; in number 3

they were from the plants in Experiment XIV, 3; and in number 4 from the plants mentioned in Experiment XVI, which had been infected by white-flies from crinkly Bamia.

It is thus apparent that the virus can readily be transferred from Til to Sakel. The symptoms of the disease on Sakel, as produced by the virus which has been passed through Til, are in no way different from those originally produced on Sakel.

21. Transmission from Bamia to Til, and Bamia to Bamia.

Experiment No. XVI.

Only one experiment on three plants has so far been carried out; the white-flies used were the offspring of those used to produce the disease on the Bamia plants mentioned in Experiment XII (*b*), no. 5. They were transferred on 10.ii.31 to three seedling Til plants, all of which became infected, the period of incubation being 15, 17 and 20 days.

This result appears surprising in view of the repeated failures to transfer the virus from Bamia to Sakel (Section **18**) and to American cotton (Section **24**) and the success attending transmission from Til to Sakel and to American cotton. It therefore seems that cotton can only be infected from Bamia if the virus has first been passed through Til.

An exact parallel has recently been recorded by Smith,[21] who failed to produce any symptoms in *Datura stramonium* by needle inoculation from a virus-carrying Di Vernon potato, unless the virus was first passed through White Burley tobacco, from which infection of the *Datura* could be easily obtained.

An attempt to infect three healthy Bamia plants by means of white-flies which had bred on crinkly Bamia (the plants mentioned in Experiment XII (*b*), no. 5, from which the virus was successfully transferred to Til) resulted in failure on all three plants.

It is thus seen that Til plants are the only ones to which the virus has so far been successfully transferred from Bamia.

22. The Disease on Hollyhocks (*Althaea rosea*), and Karkade (*Hibiscus sabdariffa*).

In February 1931 a large number of Hollyhocks growing in a garden in Wad Medani were observed all to be affected with leaf-curl. The symptoms of the disease were of the crinkle type and similar to those on Bamia—one or two of the most severely affected plants had a marked " bunchy top " appearance. White-flies were breeding on all the plants. No transmission experiments either from or to hollyhocks have been attempted, but there is little doubt that the disease is identical with that on cotton, Bamia and Til.

Owing to the poor quality of the seed available, only one Karkade plant has been raised. White-flies from crinkly Sakel cotton were transferred to this plant, and about three weeks later it showed definite symptoms of crinkle (which had probably first appeared some days previously) very similar to those manifested by Til.

23. Transmission of Virus to Watts Long Staple Cotton.

When white-flies are transferred from Sakel cotton affected by leaf-curl to healthy cotton of the type " Watts Long Staple " (or to several other varieties of cotton which are enumerated in Section **29**) the resulting symptoms are totally different from those of crinkle, a characteristic mosaic being the chief feature.

The first visible sign of the mosaic on Watts Long Staple resembles the " clearing of the veins " described by Smith (19, pl. ii, fig. 5) as the first manifestation of potato

mosaic when transferred to certain varieties of tobacco. The larger veins appear broader than normal owing to a slight chlorosis which tends to be concentrated close to their sides.

After a few days the chlorotic areas increase in size (Plate xix, fig. 1), and though often more numerous near the sides of the main veins, thus giving some appearance of symmetry in their arrangement (Plate xix, fig. 3) they also occur scattered at random over the whole leaf surface, so that the leaf becomes more or less uniformly mottled (Plate xix, fig. 2).

The pale spots always seem to originate from a veinlet and are not found isolated in the intercostal areas. Except when a leaf is viewed by transmitted light, they are much more readily visible on the upper surface of the leaf than on the lower; they vary in colour from a slightly paler green than the normal leaf to a light yellow or are even practically white.

The chlorotic spots frequently coalesce to form large pale patches, which may cover as much as half or even more of the leaf area; or there may be only one or two spots visible on an affected leaf.

The upper surface of the leaves sometimes presents a blistered appearance, and their margins are often puckered, owing presumably to the more rapid expansion of the healthy parts as compared with the chlorotic areas. In severe cases the whole leaf may be a pale yellow with a few dark green areas, which are markedly convex on the upper surface.

The leaves often become asymmetric owing to a greater concentration of chlorotic spots on one side or the other; leaves which have developed the symptoms very badly remain more or less dwarfed (Plate xix, fig. 4).

There is some tendency towards a bunchy growth, due to the internodes being shortened in a severely affected plant.

The veins themselves remain apparently normal, and no enations are produced, though in one instance one or two short dark areas on the veins have been observed on leaves of a Watts Long Staple plant experimentally infected from crinkly Sakel. These dark areas resembled the first manifestations of crinkle on Sakel cotton, but they never increased in number or intensity, nor were any produced on the younger leaves, which were all affected with mosaic. See, however, Section **25**.

When a plant has been infected for some weeks, a uniform mosaic appearance develops on the older leaves, owing to absence of chlorophyll from most of the leaf area except on narrow strips close to the principal veins. As with the very similar manifestation on old leaves of Til plants infested with crinkle (Section **19**) and more rarely of crinkly Sakel plants (Section **26**), this symptom only occurs on old leaves; it sometimes spreads down the plant, thus appearing on a leaf older than that on which the first signs of mosaic were visible, occasionally even reaching the cotyledons, though usually these are shed too soon to become affected. That this is however a feature of the virus disease, and not, for instance, due merely to old age or to direct damage by white-flies, is proved by its never having been observed on any control plants.

It should be mentioned that a curious "ridging" of the upper surface of short lengths of the veins of Watts Long Staple (and other types of American cotton) is not infrequent, the affected part of the vein being sharply triangular in section instead of being rounded. Sometimes the "ridges" diverge from the veins and traverse the intercostal areas. It might be thought that this was a slight manifestation of crinkle, appearing on the upper instead of the lower surface of the leaves, but in

fact it has nothing to do with the virus disease, as it has also been observed on control plants, both those on which uninfected white-flies have been put and those which have been kept protected from all insects.

The following direct transmissions of the virus from crinkly Sakel to Watts Long Staple have been carried out.

Experiment No. XVII.

The white-flies used had been bred on crinkly Sakel plants; they were transferred to healthy plants of Watts Long Staple, on which they were left.

No.	Number of plants in tin	Age of plants when infected (days)	Date infected white-flies put on plants	Incubation period (days)	Remarks
1	1	8	6.xi.30	23	Mosaic became severe.
2	1	31	29.xi.30	19	Do.
3	2	9	8.xii.30	21 (both)	Do.
4	2	9	8.xii.30	21 (both)	Do.
5	2	12	11.xii.30	18 (both)	Do.
6	2	12	11.xii.30	{21 45	Mosaic remained mild. No symptoms after 23 days, but definite 22 days after plant topped.
7	1	13	23.xii.30	14	Mosaic moderate.
8	2	10	31.xii.30	{12 15	Mosaic became severe.
9	1	11	1.i.31	26	Also slight trace of crinkle; mosaic partially recovered.
10	1	13	3.i.31	13	Mosaic fairly severe.
11	1	13	3.i.31	13	Mosaic became very bad.

Thus every one of the 16 Watts Long Staple plants infected by white-flies from crinkly Sakel developed the symptoms of mosaic.

The white-flies used in numbers 1, 3, 4, 5 and 7, were collected from crinkly Sakel in the field; those used in the remainder had been breeding on different crinkly Sakel plants grown under controlled conditions.

Controls.

Three experiments on 5 plants, using white-flies that had bred on Lubia; 2 experiments on 5 plants using white-flies that had bred on uninfected Sakel; 3 experiments on 9 plants using white-flies that had bred on uninfected Watts Long Staple; and 3 experiments on 13 plants on which no insects of any description were placed; all produced plants which grew entirely normally, without any trace of the symptoms of mosaic.

The following transmission experiments show that the virus is as readily transmitted by white-flies from Watts Long Staple with mosaic to healthy plants of the same variety, as it is from crinkly Sakel to Watts Long Staple.

Experiment No. XVIII.

The white-flies used had been breeding on mosaic plants produced in Experiment XVII. They were transferred to healthy plants of Watts Long Staple on which they were left.

No.	Number of plants in tin	Age of plants when infected (days)	Date infected white-flies put on plants	Incubation period (days)	Remarks
1	2	8	29.xii.30	16, 25	Both developed severe mosaic.
2	2	10	31.xii.30	14, 16	Ditto.
3	3	7	5.i.31	14 (all)	All developed very severe mosaic.
4	3	9	7.i.31	12, 14, 14	One developed rather severe mosaic, the other two remained less badly affected.
5	2	9	10.i.31	16 (both)	Both developed severe mosaic.
6	1	9	10.i.31	16	Severe mosaic.
7	2	52	20.i.31	18 (both)	Both developed rather severe mosaic.
8	2	41	31.i.31	12, 15	Both developed moderate mosaic.

Thus every one of the 17 Watts Long Staple plants infected by white-flies from Watts Long Staple plants with mosaic, developed similar symptoms.

Failure to transmit mosaic by needle inoculations.

Attempts were made to transmit the mosaic of Watts Long Staple to five plants each of Watts Long Staple, Sakel and Bamia, by means of needle scratches through drops of inoculum composed of freshly expressed unfiltered juice from Watts Long Staple plants with severe mosaic.

In no instance was transmission obtained.

Partial recovery of Watts Long Staple cotton from the symptoms of mosaic.

No case of apparently complete recovery from mosaic has been noticed ; a very definite partial recovery was, however, observed on the plants in Experiment XVII, numbers 1, 7 and 9, about 5—6 weeks after the date of infection. Numbers 1 and 7 were then topped ; whereupon the symptoms recurring on the new growth were as severe or even more so than those originally produced. Number 9 was not topped, and the mosaic on the new leaves remained slight.

Partial recovery from mosaic has also been observed on a number of Watts Long Staple plants growing in the field ; though no detailed records have been kept, it is thought that the proportion so recovering is somewhat greater than the proportion of Sakel plants which show a partial recovery from crinkle.

The incubation period of the virus in Watts Long Staple cotton.

As is the case with the crinkle manifestation of leaf-curl in Sakel, practically no reasons can be given for the considerable variations in the incubation period of the mosaic symptoms in Watts Long Staple.

The following table gives the recorded times of the incubation period in all the successful transmissions to Watts Long Staple which have been made by white-flies

(whether from crinkly Sakel or mosaic Watts Long Staple) including all methods which can be considered comparable to those recorded in Section 6 for the incubation periods of crinkle in Sakel.

Incubation period (days)	Number of observed examples	Approximate percentage in each category
8–10	Nil	0
11–13	18	34
14–16	20	38
17–19	7	13
20–22	5	9
23–25	2	4
26–28	1	2

Allowing for the fact that the first signs of mosaic are much more difficult to diagnose with certainty than those of crinkle, it seems probable that the incubation periods of the two aspects of the virus are practically similar.

24. Attempted Transmission from Bamia to Watts Long Staple.

Experiment No. XIX.

Only two experiments on three plants have been undertaken, but in neither case has the slightest symptom of mosaic been produced on a Watts Long Staple plant when white-flies from crinkly Bamia were transferred to it.

The white-flies used had been bred on the fairly badly affected Bamia plants produced in Experiment XII (*b*), numbers 5 and 6.

This result therefore agrees with the failure to transmit the crinkle manifestation of the virus from Bamia to Sakel (Experiment XIII).

25. Transmission from Til to Watts Long Staple.

Experiment No. XX.

(*a*) White-flies which had been breeding on the crinkly and curled Til plants produced in Experiment XIV, no. 1, were transferred on 10.i.31 to two healthy Watts Long Staple plants in one tin. Symptoms of mosaic appeared on one plant after 15 days and on the other after 16 days. One plant subsequently developed rather severe symptoms, and also a few slight traces of crinkle, while on the other the mosaic remained mild and showed some tendency to recover, and there were no signs of crinkle.

(*b*) White-flies which had been breeding on the crinkly and curled Til plants produced in Experiment XVI (which had been infected by white-flies from crinkly Bamia) were transferred on 14.iii.31 to two healthy Watts Long Staple plants.

Both these plants developed both mosaic and crinkle, on one plant the traces of crinkle were few and slight, but on the other, though mild in comparison with the ordinary symptoms on Sakel, they were readily observable and affected several leaves. On both plants the crinkle appeared first, after 11 and 15 days, while the mosaic though suspected before, was not conspicuous until 21 days from the date of infection.

Further experiments should be made before it can be stated whether there is any significance in the fact that three out of four Watts Long Staple plants infected from Til developed slight crinkle as well as mosaic, while only one out of the 16 plants infected from Sakel (in Experiment XVII) did so, and none of the 31 plants in Experments XVIII and XXII.

26. Transmission from Watts Long Staple to Sakel.

In view of the ease with which mosaic can be produced on Watts Long Staple when infected by white-flies from crinkly Sakel, it was expected that the virus could be transmitted back from a Watts Long Staple plant with mosaic to healthy Sakel, and that the symptoms of crinkle would appear.

Such, however, is not the case.

Experiment No. XXI.

Twenty-four healthy Sakel plants, grown in 11 tins, were infected by means of white-flies which had bred on various of the Watts Long Staple plants with mosaic, produced in Experiments XVII and XVIII.

No symptoms, either of crinkle or mosaic or of any other manifestation of the virus, could be detected on any of these 24 plants, with the exception that one of them, some two months after the infected white-flies were put on it, showed on its oldest leaves rather vague traces of the uniform mosaic appearance (p. 347) which is common on old leaves of mosaic Watts Long Staple cotton and crinkly Til, and has occasionally been observed on the old leaves of crinkly Sakel.

Otherwise all these plants were apparently normal healthy Sakel plants. That they did in fact harbour the virus of leaf-curl in its mosaic aspect, but in an invisible form, is proved by the following :—

Experiment No. XXII.

Healthy Watts Long Staple plants were infected by means of white-flies which had bred on the apparently normal Sakel plants produced in the previous experiment. Those used on nos. 1–4 all came from the plants in one tin, the remaining three from plants in three different tins.

No.	Number of plants in tin	Date white-flies put on the healthy Watts Long Staple plants	Incubation period (days)	Remarks
1	3	31.i.31	11 (two plants) 13 (one plant)	All developed very severe mosaic.
2	4	31.i.31	11 15 16 (two plants)	3 developed very severe mosaic, 1 rather milder.
3	2	10.ii.31	11 (both)	Both developed very severe mosaic.
4	2	10.ii.31	11 (both)	Both developed rather severe mosaic.
5	1	17.ii.31	17	Mosaic remained fairly mild.
6	2	17.ii.31	11 13	Mosaic became severe.
7	2	17.ii.31	12 13	Ditto.

The symptoms of mosaic on these 16 plants were in no way different from those produced by direct transmission of the virus by white-flies from Sakel with crinkle, or from Watts Long Staple with mosaic ; that is to say, passage of the virus through Sakel, in which the symptoms of mosaic are entirely masked, does not affect its appearance when re-transferred to a plant capable of showing mosaic. Certainly there is no suggestion of attenuation of the virus, since, if anything, the average

intensity of the mosaic symptoms on these 16 plants was rather greater than that on plants infected direct from crinkly Sakel or from other plants of Watts Long Staple.

It was thought just possible that, although Sakel when infected from plants with mosaic shows no visible symptoms, if the virus were transferred from such apparently healthy Sakel plants to other known healthy Sakel plants, visible symptoms might be produced.

Judging, however, by two experiments on four Sakel plants, to which were transferred white-flies which had bred on Sakel plants apparently unaffected by white-flies from Watts Long Staple plants with mosaic, this is not the case, as all four Sakel plants remained apparently normal. It is not yet known if these plants still retain the virus in what may be termed the " invisible but transmissible mosaic " form, but it is thought probable that such will be found to be the case.

27. Minor Experiments on Transmission of Mosaic to Watts Long Staple.

(1) White-flies from a crinkly Sakel plant were transferred to a number of healthy Sakel plants (those used in Experiment III, which subsequently all became crinkly), and the survivors after 7 days were placed on two healthy Watts Long Staple plants. These both developed mosaic, the incubation periods being 14 and 19 days. This is in agreement with Experiment IX (*b*) 2.

(2) Uninfected white-flies, which had been allowed to feed for 9¾ hours on a crinkly Sakel plant, were transferred to two healthy Watts Long Staple plants, which developed mosaic. The symptoms on both plants were at first mild and indeterminate ; they did not become definite until 32 days from the date of infection, but subsequently became very severe. This corresponds with Experiment X, no. 8.

Uninfected white-flies which had been allowed to feed for 3⅓ hours on a crinkly Sakel plant, successfully transmitted mosaic to a single healthy Watts Long Staple plant. Compare Experiment X, nos. 12 and 13.

(3) White-flies which had bred on Sakel plants unaffected by white-flies from crinkly Bamia (Experiment XIII) failed to transmit the disease to six healthy plants of Watts Long Staple.

(4) White-flies which had bred on Watts Long Staple plants unaffected by white-flies from crinkly Bamia (Experiment XIX) failed to transmit any symptoms to three healthy plants of Watts Long Staple, or to three healthy plants of Sakel.

28. Crinkle and Mosaic considered to be different Manifestations of one Virus.

It has been assumed in the foregoing pages that only one virus is concerned in the production of both crinkle and mosaic, and that the symptoms produced by this one virus vary according to the host-plant. It could, however, be suggested that the virus of crinkle and that of mosaic are distinct, and that some host-plants can only be infected by one, some by the other, and a few by both. It is nevertheless thought that this supposition is less probable than the former one for the following reasons :—

(1) It is difficult to believe that apparently every Sakel plant showing the symptoms of crinkle is a carrier of a different virus (mosaic) in a masked condition.

(2) Transmission of both crinkle and mosaic seems only to be obtainable with white-flies, and neither can be transmitted by needle.

(3) Apart from their entirely different appearance, crinkle and mosaic both behave in very similar ways, *e.g.*, as regards their incubation period in the host-plant, occasional partial recovery, the effect of topping the plant, the ability of both to be transferred through Til, but not through Bamia, etc.

(4) The only argument in favour of two separate viruses being concerned is that although mosaic can readily be produced on a suitable host-plant by transmission

from a crinkly plant, crinkle has not yet been produced on any host by transmission from a plant with mosaic, although it has been clearly shown that the power to transmit mosaic again to a plant capable of showing it is not lost by passing the virus through Sakel which is incapable of showing it.

It is possible to adduce several theories to explain this fact, even on the assumption that only one virus is concerned, but in the present state of our knowledge of this virus disease of cotton, tentative explanations are of little value.

Many of the results obtained by Smith (*l.c. passim*†) show that a single virus may produce entirely different symptoms on different host-plants, which to a certain extent confirms the opinion that only the one virus of leaf-curl is concerned in producing both crinkle and mosaic. In any case this seems to be the easiest theory to adopt in default of definite proof to the contrary.

29. Transmission of Virus to other Species and Varieties of Cotton.

All the transmission experiments so far described have been made either on Sakel (*Gossypium peruvianum* × *barbadense*), which is the cotton planted over the whole of the Gezira area, or on Watts Long Staple (*G. hirsutum*). Mr. M. A. Bailey (Government Plant Breeder) and Mr. A. R. Lambert (Inspector of Botanical Work, Gezira Research Farm) kindly supplied the writer with the seeds of a number of other species and varieties of cotton, in order to ascertain the effect, if any, of the virus upon them.

For convenience, the following lists include all cottons and other Malvaceous plants on which controlled experiments on transmission by white-flies from crinkly Sakel plants have been made, and a few on which, although no transmission experiments have yet been attempted, the symptoms observed in the field were so nearly identical as to make it reasonably certain that they had been infected by the same virus; these latter are marked with an asterisk. The references in square brackets are to the Government Plant Breeder's records.

(*a*) The following, when infected by white-flies from crinkly Sakel, have developed crinkle only :—

(1) Sakel (*G. peruvianum* × *barbadense*).
(2) " 310 Balls " [S.R. (C) 3].
(3) " Casuli " [S.R. (C) 5].
(4) " Pilion " [S.R. (C) 4].
(5) " S.I.D. I, 8 " [S.R. (C) 154].
    All the above developed ordinary " Sakel-type " crinkle.
(6) " Afifi " [7/30.1].
    Ordinary " Sakel-type " crinkle, rather severe.
(7) Hybrid, F.8. Sakel × Sea Island [H.12/30.6].
    Enations very conspicuous, but comparatively few and scattered.
(8) Indigenous " Belwa " (sp. ?)
    Crinkle mild, tending to recover on later growth.
(9) Brazil perennial " Quebradinho " (? *G. vitifolium*).
    Enations very conspicuous, and foliar outgrowths produced, but long lengths of the veins on all leaves remain unaffected.
(10) American (*G. hirsutum*) [A. 24/30.32].
    Enations fairly conspicuous, but scattered and few in number. Tendency to recover on new growth.
(11) *Certain hybrid " rogues " noticed among the Sakel sown in the Gezira.
    Symptoms vary from very mild to severe crinkle with or without definite " curling."

† Especially his most recent paper,[21] which has only come to hand after the above was written.

12) " Ishan A " (*G. vitifolium*) from Nigeria.
Only one plant has been raised, as the seed supplied germinated very badly. This plant developed crinkle with large but rather scattered enations, similar to those on (9). Some of the leaves were distinctly curled upwards. It should be noted that this strain of cotton is said to be very highly resistant to leaf-curl in Nigeria.

(13) *Hibiscus cannabinus* (Til).
Symptoms described in Section **19.**

(14) *Hibiscus esculentus* (Bamia).
Symptoms described in Section **17.**

(16)**Althaea rosea* (Hollyhock).
Symptoms described in Section **22.**

(15) *Hibiscus sabdariffa* (Karkade).
Only one plant raised ; symptoms like those on Til.

(*b*) The following, when infected by white-flies from crinkly Sakel, have developed mosaic only :—

(1) American " Watts Long Staple " (*G. hirsutum*).
Very rarely also with extremely slight manifestations of crinkle, but see also Section **25.**

(2) American " Parnell's U.4 " (*G. hirsutum*).
Symptoms similar to those of Watts Long Staple, rarely with slight manifestations of crinkle.

(3)*American " Parnell's Z. I." (*G. hirsutum*).
Symptoms similar to those on Watts Long Staple.

(4) Indigenous " Mixed Beladi " (sp. ?).
Symptoms similar to the severest noticed on Watts Long Staple.

(5) Indigenous " Mumtaz " (sp. ?).
Rather inconspicuous pale green mosaic evenly distributed over the leaf surface.

(6) Brazil perennial " Moco."
Mosaic rather inconspicuous, similar to the last.

(7)*Hybrid, Brazil Perennial × Upland.
Mosaic similar to that on Watts Long Staple.

(8)*Certain hybrid " rogues " noticed among the Sakel sown in the Gezira.
Symptoms very variable in intensity, mostly similar to those on Watts Long Staple.

(9) Indian " Bengal " (*G. nanking*, var.).
" Clearing of the veins," but apparently no further symptoms produced.

(10) Asiatic (*G. nanking*, var. *nadam*) [R.P. 12/30.4].
" Clearing of the veins," but no large chlorotic areas subsequently produced. It is possible that (9) and (10), the former supplied by Mr. Lambert and the latter by Mr. Bailey, are identical. These are the only Asiatic cottons which have developed any symptoms of the disease.

(*c*) The following, when infected by white-flies from crinkly Sakel, have developed mosaic and crinkle together in the same plant :—

(1) American (*G. hirsutum*) seed from cotton grown near Rufa'a, Blue Nile Province.
Mosaic symptoms severe, similar to those on Watts Long Staple ; crinkle comparatively mild.

(2)*Certain hybrid " rogues " noticed among the Sakel sown in the Gezira.
Almost every variation from mild to severe mosaic and crinkle, and combination of the two, has been observed.

(*d*) The following, when white-flies from crinkly Sakel were transferred to them, have developed no visible symptoms :—

(1) Asiatic " Cyprus " (*G. herbaceum*).
(2) Asiatic " Afghan " (*G. herbaceum*) [R.P. 14/30.6].
(3) Asiatic (*G. herbaceum*) [R.P. 13/30.2].
(4) Asiatic " Punjab " (*G. arboreum*) [R.P. 6/30.8].
(5) Asiatic " Nuba Red " (*G. arboreum* ? var. *sanguineum*) [R.P. 6/30.8].
(6) Asiatic (*G. obtusifolium*, var. *africanum* × *nanking*) [R.P. 9/30.6].
(7) Indigenous " Siwa Oasis " (red boll) (*G. obtusifolium* ? var.).
(8)*Certain hybrid " rogues " noticed among the Sakel sown in the Gezira.
(9) *Sida* sp.
(10)* " Hambook " (*Abutilon glaucum*). A common weed in and near cotton fields, and readily fed on by white-flies, but no symptoms have ever been observed on it.

30. Retransmission from other Varieties of Cotton to Sakel and Watts Long Staple

Very few attempts to re-transmit the virus from any of the varieties of cotto mentioned in the foregoing Section have yet been carried out. However, such few as have been done appear to be worth recording.

(1) White-flies which had bred on plants of *G. obtusifolium* mentioned in (*d*) 7 (which failed to develop any symptoms when white-flies from crinkly Sakel were placed upon them) were transferred to six healthy Sakel plants. None of these developed any symptoms.

(2) White-flies which had bred on plants of *G. herbaceum* mentioned in (*d*) 1 (which also developed no symptoms) were transferred to five healthy Sakel plants and three healthy Watts Long Staple plants. All these remained normal.

(3) White-flies which had bred on plants of *G. nanking* mentioned in (*b*) 9 (which developed slight traces of mosaic) were transferred to three healthy plants of Watts Long Staple. One of these plants died, the other two developed very slight and possibly doubtful symptoms of mosaic.

(4) White-flies which had been breeding on plants of the variety of American cotton mentioned in (*c*) 1, which developed severe mosaic and mild crinkle, were transferred to 7 healthy Sakel plants, on which no visible symptoms were produced.

This may possibly be construed as an additional argument in favour of only one virus being concerned in the manifestation of both crinkle and mosaic, since, if two distinct viruses were present, there seems to be no reason why the crinkle should not have been transmitted.

It may also be mentioned that typical mosaic, but no trace of crinkle, has been produced on this variety of American cotton by means of white-flies which had bred on Watts Long Staple with mosaic and on Sakel with " invisible but transmissible " mosaic (Experiment XXII). Four plants were used in each case, successful transmission being obtained to all.

31. Miscellaneous Transmission Experiments.

(1) What is presumed to be a mosaic, but quite distinct from any produced on any of the varieties of cotton previously mentioned, was noticed on two plants in a cotton plot on the Gezira Research Farm. The plot was sown with Sakel seed, and the two plants were apparently true to type. Both the plants, like nearly all the others in the same plot, showed symptoms of crinkle, though not very severely. In addition many of the leaves had narrow pale green streaks on either side of the main

veins and numerous small circular pale green spots all over the intercostal areas. Uninfected white-flies were enclosed for 48 hours on a branch of one of these plants, which showed the mosaic symptoms but had no trace of crinkle. These were transferred to two healthy Sakel plants, which developed ordinary and rather severe crinkle (thus confirming Experiment VI), but the mosaic was not transmitted.

(2) Uninfected white-flies were kept for 8 hours in a chamber in which was placed a filter paper kept wet with the diluted juice expressed from crinkly Sakel leaves. They were then transferred to two healthy Sakel plants, but in neither case was transmission of the virus obtained.

(3) It was thought possible that Sakel plants, apparently normal but known to be infected with " invisible but transmissible " mosaic, might possibly be immune from further infection by white-flies from crinkly Sakel. This, however, is not the case, as white-flies from crinkly Sakel were transferred to five Sakel plants previously infected with " invisible but transmissible " mosaic (Experiment XXI) and all five developed crinkle within 9–11 days.

32. Notes on suspected Virus Diseases of other Plants.

Although, perhaps, the majority of virus diseases appear to be restricted to plants belonging to a single Natural Order, a certain number of cases of inter-transmissibility between plants of different Natural Orders have been definitely proved. It is, therefore, possible that the leaf-curl virus which produces crinkle and mosaic in cotton and certain other Malvaceae may infect other plants in which entirely different symptoms may be manifested.

So far, the only such plants on which symptoms which might be those of a virus disease and on which observations and a few experiments have been made are the following :—

(1) Lubia (*Dolichos lablab*).

Lubia plants have occasionally been noticed on which the leaves, especially the younger ones, had a very conspicuous wrinkled appearance. Superficially such affected leaves resemble those of crinkly cotton, but in Lubia the " wrinkling " is due to contraction of the lamina, the veins remaining normal. Some of the plants thus affected also had rather inconspicuous chlorotic spots irregularly distributed over the leaf area.

Uninfected white-flies were enclosed on such plants for 48 hours and then transferred to eight healthy Lubia plants and to two healthy Sakel plants. None of these developed symptoms of any sort ; it is therefore probable that if this condition of Lubia is due to a virus disease at all, it is not carried by white-flies, nor is it likely to be connected in any way with the virus disease of cotton.

(2) French Beans (*Phaseolus vulgaris*).

A very similar " wrinkling " of French Beans, even more marked than that on Lubia, but not accompanied by chlorotic spots, was noticed in one of the gardens on the Gezira Research Farm. Almost all the plants were affected, and their growth was obviously impaired. Uninfected white-flies were enclosed on one of the most badly affected plants, and after 48 hours transferred to two healthy Sakel plants, neither of which developed any symptoms. Attempts to inoculate Lubia by needle from " wrinkled " French beans also failed.

(3) Gubein (*Solanum dubium*).

Gubein, an abundant weed all over the Gezira, is very frequently affected with indistinct yellowish spots on the leaves, which often take the form of incomplete rings and are very similar in appearance to the " nebulous ring-spot " described and figured by Smith (19, Plate i, fig. 4) on Virginia and White Burley tobaccos.

All attempts to grow Gubein from seed have so far failed ; it has therefore not been possible to attempt to inoculate healthy plants by any methods. Uninfected white-flies have been enclosed on Gubein plants showing ring-spot symptoms for 48–72 hours, and transferred to nine healthy Sakel plants and three healthy Watts Long Staple plants. None of these, however, developed any symptoms of any sort.

(4) Tomatoes (*Lycopersicum esculentum*).

Tomatoes affected by a disease apparently similar to crinkle of cotton have been observed in various places. The symptoms vary considerably in different localities—perhaps according to the variety of tomato, as it has usually been impossible to ascertain what this is—and may not all be produced by the same disease.

In a garden in Khartoum, a number of plants have been observed which had short lengths of the veins thickened and darkened, exactly as in a rather mild case of crinkle on Sakel cotton, and a considerable number of cup-shaped foliar outgrowths (some of them nearly 1 cm. in length) just as on a Sakel plant badly infected by crinkle.

In a garden near Barakat in the Gezira, most of the tomato plants had a well-marked leaf-curl and a noticeable " bunchy-top " appearance. Cup-shaped outgrowths up to 8 mm. in length were not uncommon, but no thickening and darkening of the veins could be found. Similar plants have also been found on the river bank near Hag Abdalla in the south of the Gezira, while on the river bank a few miles north of the Gezira Research Farm, and in gardens on the Farm itself, tomatoes are commonly affected with " curl " and " bunchy top," but no foliar outgrowths have been seen.

A preliminary attempt to infect five tomato plants grown under cover, by means of white-flies from crinkly Sakel cotton, resulted in failure, no symptoms of any sort being produced on the tomatoes.

In view of the remarkable similarity between these symptoms on tomatoes and crinkle of cotton, and the practical importance of ascertaining whether crinkle can be carried in plants other than those belonging to the Malvaceae, further experiments with tomatoes are now being undertaken.

33. Leaf-curl in the Gezira during the Season 1930–31.

It is universally agreed that leaf-curl has become a much more serious menace than it was in the previous season. It has not been possible, owing to the time required for other experiments, to ascertain the exact rate of spread of the disease over the whole Gezira, but judging from the only accurate counts made, on the Gezira Research Farm and in Tebub and Tayiba Blocks, and from casual observations elsewhere, 75 per cent. of the plants had become infected 15–25 days earlier than in the previous season, while the 90–95 per cent. mark was reached almost everywhere about the second week in November, compared with the end of November or well on into December for the 1929–30 season.

The only exceptions to this early and rapid rate of increase of the disease occurred in those areas in the north and north-west which were under cultivation for the first season. Here the progress of leaf-curl was very much the same as it was in the previous season in those blocks then irrigated for the first time (7, p. 129). That is to say, in November the number of diseased plants was very small, probably less than one in a thousand, except in those parts of the new blocks adjacent to land which had been under cotton in the previous season. The rate of increase was slow until February 1931, when it accelerated rapidly.

It may be said that for some reason as yet unknown, white-flies continue breeding in numbers in the north of the Gezira much later—till February and March—than they do in the centre and south.

Not only did the disease spread earlier and faster than in the previous season, but the proportion of plants very badly affected, and the average intensity of the symptoms of crinkle on the crop as a whole, were undoubtedly much greater.

It is probably impossible to plan an experiment to show accurately the extent of the loss to the crop caused by leaf-curl on a sufficiently large scale to be of value, and no such experiment has been attempted. However, the writer's belief, based on observations only, is that during the 1930–31 season leaf-curl caused an average reduction in the yield of at least half a kantar per feddan, and possibly nearly double this amount.

The disease seems to cause the greatest damage when, as so often happens, a young plant has been attacked by " Black-arm " (*Bacterium malvacearum*, E.F.S.) from which it has recovered, only to develop severe crinkle on the fresh growth.

34. Possibilities of Control.

As with many virus diseases, it is possible that the most promising line of control of leaf-curl may be the selection of resistant strains, with which, as already stated (Section **9**), an encouraging start has already been made by the Government Plant Breeder and the Inspector of Botanical Work.

But, at the best, several years must elapse before enough seed of a resistant strain can be produced to sow the whole Gezira ; meanwhile attempts must be made to limit the damage in other ways.

As it is exceedingly improbable that any treatment can alleviate the effects of the disease once a plant is infected, the only available methods are control of the white-flies or (and) control of the initial sources of infection at the beginning of the cotton season.

The former will not be touched upon here, as a study of the seasonal life-history of *B. gossypiperda*, the effects of parasites upon it, etc., is being undertaken by Mr. A. P. G. Michelmore, Assistant Entomologist.

There can be little doubt that at any rate the principal initial source of infection is the accidental " ratoon " cotton surviving from the previous season, the new leaves produced by which are almost invariably very badly affected with the crinkle symptoms of leaf-curl.

The rotation practised in the Gezira, up to and including the 1930–31 season, has been (1) cotton ; (2) Lubia and Dura ; (3) fallow. The cotton is cut out during May and towards the end of July or early in August, Lubia is sown on 6 out of the 10 feddans comprising the cotton area of one holding, and Dura on the other 4 feddans.

Although the rains do not become heavy until July and August, there are always early showers in June and usually in May sufficient to keep alive a certain number of the cotton roots until the land is irrigated for sowing the Lubia and Dura. New and heavily crinkled growth is then produced by these roots, which, growing up as it does with the Lubia and Dura, easily escapes notice and would be very difficult to eradicate. No one who has not walked through a Lubia field making a careful search would suspect the presence of such a large number of " ratoon " cotton plants as actually exists.

Now white-flies, during 1930, were conspicuous only by their absence in June and July. They were first noticed about the middle of August on weeds which had come up with the rains, and shortly afterwards on the young Lubia and cotton.

The fact that no crinkle was observed on the cotton till the end of September is an indication, not only that infection is not carried in the seed (Section **4**), but also that the first white-flies to appear in August are not infective, since if they were, cotton would have begun to show symptoms of the disease considerably earlier than it did.

It is believed that the first cotton plants to show symptoms of crinkle have become infected by means of white-flies which have been feeding on the "ratoon" crinkly plants among the Lubia and have thence spread to the adjacent cotton. As soon as a very few plants have become infected in this manner, the rapid increase of the disease in October is assured, owing to the large numbers of white-flies then present.

Roguing out infected plants as they appear in the field is obviously impracticable, and was moreover proved useless by an experiment undertaken during October 1929, before the real cause of the spread of the disease had been ascertained.

White-flies certainly make voluntary flights, particularly in the early morning, though nothing is known as to how far they fly; and there seems no reason to assume that they may not be blown long distances on the wind, especially perhaps if carried high up into the air by "dust devils."

This theory at any rate accounts for the more sporadic and somewhat later first appearance of crinkle in the blocks in the north and north-west not previously cultivated, both during the past season and the previous one (1929–30). It therefore seems highly probable that if it is possible to eradicate "ratoon" cotton from August onwards, the reservoir of infection will be abolished.

Largely with this end in view, the Sudan Plantations Syndicate has decided, as a temporary measure starting with the coming season (1931–32), to stop growing Lubia (at any rate immediately following cotton) and adopt the rotation: (1) cotton; (2) fallow; (3) fallow. The necessary Dura will be sown year after year on land specially set apart.

The land from which the cotton has been cut out will, therefore, not be irrigated, and "ratoon" plants should not come up unless the rainfall is exceptionally heavy. If it should be, the warning may be given that "ratoon" cotton will escape notice just as easily among the thick growth of weeds that will be produced, as it previously has done among Lubia.

The alternative method of preventing "ratoon" plants coming up, that of cutting out the old plants in May several inches below soil level, though it might be successful, is too suggestive of hard work to make it likely that it could be efficiently carried out.

It must again be emphasised that, even though there are at present no indications of it, it is conceivable that the virus of leaf-curl could be carried in a plant which might show no symptoms of any disease.

However, if a determined effort is made to eradicate all "ratoon" cotton plants before the white-flies appear in August, the results may be awaited, if not with complete confidence, at least with considerable interest and some degree of hope.

35. Summary.

The reasons for adopting the name "leaf-curl" for the virus disease which is manifested by symptoms of "leaf-crinkle" on certain varieties of cotton, and by "mosaic" on certain others, are discussed.

A brief review is given of the very few references in previous literature which are relevant to leaf-curl.

Up to the end of February 1931, 168 straightforward attempts had been made to transmit crinkle from Sakel cotton to Sakel by means of white-flies (*Bemisia gossypiperda*, Misra & Lamba), of which no fewer than 157 were successful. No transmission was obtained with any other insects.

A single white-fly can transmit the disease to a healthy plant, though infection is less regularly obtained when one or only a few white-flies are used.

There is a large amount of negative evidence which indicates that the virus is not transmitted through the seed of Sakel cotton. There is also no evidence that it can be transmitted through the soil.

In nearly 200 controlled experiments, the incubation period of the virus in the plant varied from 8 to 34 days, but over two-thirds of the recorded periods were between 11 and 19 days. Possible causes of the variation in the incubation period are discussed.

Little is known with certainty about the factors which influence the severity of the disease.

At least one case of complete recovery from the disease appears to have been observed. Partial recovery is not infrequent.

Details are given of observations and experiments made on three strains of Sakel cotton selected for resistance to crinkle. Though none of them was immune, two at least showed a high degree of comparative resistance, and a greater tendency to recover than ordinary Sakel.

White-flies can pick up the virus from those parts of an infected Sakel plant which show no symptoms, and transmit the disease to healthy Sakel. It is at present rather doubtful whether they can pick up the virus from a plant which has been infected but before the symptoms develop.

In order to transmit the disease, it is not necessary that white-flies should have fed on crinkly plants as adults, provided that they have done so as larvae.

White-flies which have picked up the virus remain capable of transmitting it for seven days, and very probably throughout their life.

Uninfected adult white-flies can pick up the virus from crinkly Sakel in just over three hours (and possibly in a shorter time). Transmission was, however, only obtained on two plants out of five, when the time available for picking up the disease was three hours and twenty minutes. When it was four hours and thirty minutes or longer, transmission was obtained in every case. Infected white-flies can transmit the disease to healthy Sakel plants in 30 minutes, and the whole process of infection of the white-flies and of the healthy plant has been accomplished in 6 hours 30 minutes.

The virus cannot be transmitted through the egg of the white-fly.

Crinkle can be transmitted by white-flies from Sakel cotton to Bamia (*Hibiscus esculentus*, L.) to Til (*Hibiscus cannabinus*, L.) and to Karkade (*Hibiscus sabdariffa*, L.). The symptoms on these plants resemble fairly closely those on Sakel.

The virus is readily transmitted back from Til to Sakel, but re-transmission from Bamia to Sakel has not yet been obtained; although transmission from Bamia to Til, and from these infected Til plants to Sakel, has been successfully accomplished. In order to infect Sakel from Bamia it therefore appears necessary to pass the virus through Til.

Crinkle has also been observed on garden Hollyhocks.

When white-flies from crinkly Sakel are transferred to American cotton of the variety Watts Long Staple, a conspicuous mosaic is regularly produced, but none of the ordinary symptoms of crinkle appear, except occasionally the faintest traces which do not persist. Mosaic can also be readily transferred by white-flies from infected plants of Watts Long Staple to healthy plants of the same variety.

Attempts to transmit it by needle have failed.

No case of complete recovery from mosaic has been recorded, but partial recovery, as with crinkle on Sakel, is not uncommon.

The incubation period of the mosaic manifestation of the virus in Watts Long Staple is similar to that of crinkle in Sakel.

White-flies from crinkly Bamia have not produced any symptoms on Watts Long Staple, but typical mosaic is carried by white-flies from crinkly Til.

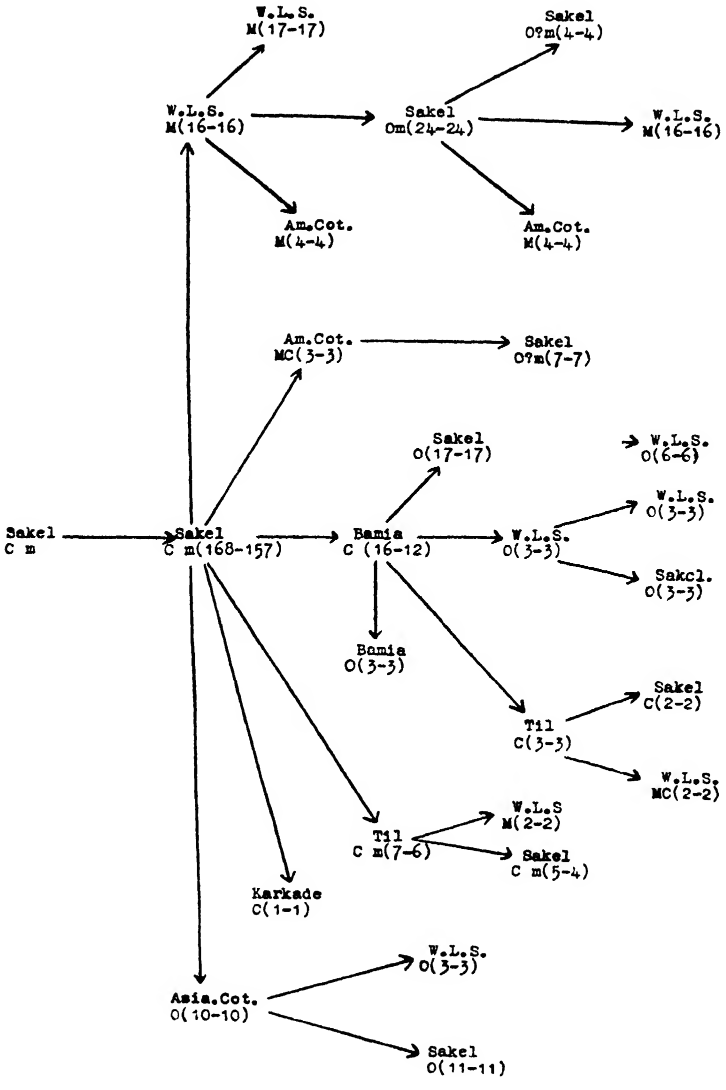

Fig. 1. Diagram of the principal experiments on the transmission of the Leaf-curl Virus of cotton, by means of White-flies. Sakel = Sakel Cotton (*G. peruvianum* x *barbadense*); W.L.S. = Watts Long Staple Cotton (*G. hirsutum*); Am. Cot. = variety of American Cotton (*G. hirsutum*) mentioned in Section **29**, *c*, 1; Asia. Cot. = Asiatic Cottons (*G. herbaceum* and *G. obtusifolium*) mentioned in Section **29**, *d*, 1 and 7; Bamia = *Hibiscus esculentus*; Til = *Hibiscus cannabinus*; Karkade = *Hibiscus sabdariffa*; C = visible symptoms of Crinkle; M = visible symptoms of Mosaic; m = invisible but transmissible Mosaic; O = no visible symptoms. The first figure in brackets is the total number of plants to which transmission was attempted in each experiment; the second figure is the number of plants on which it was successful as indicated by the letter; thus C (16–12) means that 12 plants developed crinkle out of the 16 to which transmission was attempted; O (10–10) means that all the 10 plants on which the experiment was made failed to develop any symptoms of any sort.

When white-flies are transferred from Watts Long Staple plants with mosaic to healthy Sakel, no symptoms of either crinkle or mosaic are manifested, but it is shown that such Sakel plants harbour the virus in a masked form, since when white-flies re-transmit it from them to healthy Watts Long Staple plants, typical mosaic is produced.

Minor experiments on the transmission of mosaic show that it behaves similarly to crinkle.

Reasons are given for considering that crinkle and mosaic are different aspects of one virus, the symptoms of which vary according to the host-plant.

Lists are given of a number of other varieties of cotton to which transmission of the virus by white-flies has been attempted. Some of these develop crinkle only, some mosaic only, a few may show the symptoms of both crinkle and mosaic in the same plant, while on some—particularly Asiatic cottons—no symptoms have been produced. There is no indication that such plants harbour the virus in a masked but transmissible form. A few minor transmission experiments are described.

Possible virus diseases have been observed on Lubia, French Beans, and Gubein (*Solanum dubium*). These, however, if virus diseases at all, seem to have no connection with leaf-curl of cotton.

A condition very similar to crinkle of cotton has been observed on tomatoes. Further experiments are required before it can be said whether the diseases are identical.

During the 1930–31 season in the Gezira, leaf-curl spread earlier and faster than during the previous season, and the general intensity of the disease was more severe. The extent of the damage caused by it is not known with any certainty, but is believed to be between one half and one kantar per feddan. Apart from the selection of resistant strains of cotton, the only possibilities for the control of leaf-curl lie in control of the white-flies or the control of the initial sources of infection early in the season. The former is being investigated by another worker. It is believed that the virus is carried over from one season to the next at any rate mainly in the ratoon cotton plants which survive the " dead " season and produce new growth—which is almost always crinkly—when the land which had been under cotton is irrigated for Lubia and Dura in August.

It is hoped that the new rotation proposed by the Sudan Plantations Syndicate will make it possible to eradicate this ratoon cotton.

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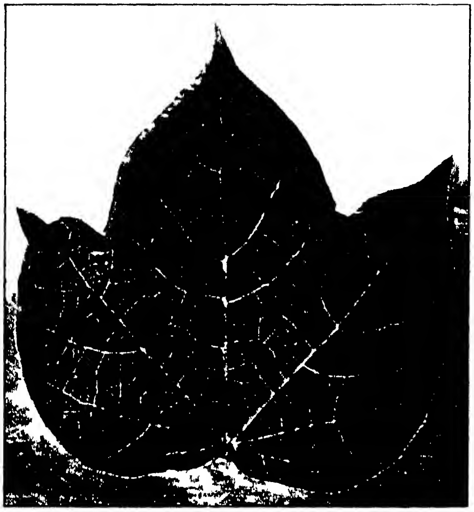

Fig. 1. First symptoms: short lengths of numerous veins darkened.

Fig. 2. Very severe symptoms: note cup-shaped foliar outgrowths.

Fig. 3. A typical leaf with moderately severe symptoms.

Sakellaridis cotton with symptoms of crinkle.

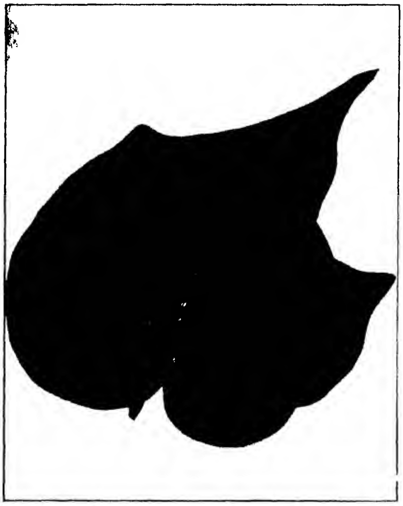

Fig 1. Mild symptoms

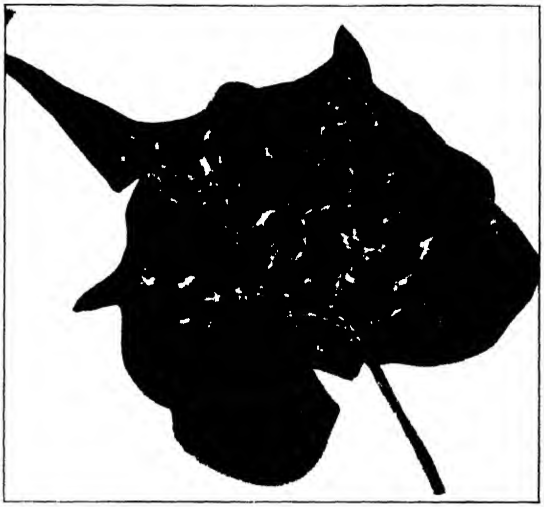

Fig 2. Rather severe symptoms

Fig 3 The chlorosis tending to be concentrated close to the veins

Fig. 4 Distortion owing to one side being more severely affected than the other

Watts Long Staple cotton with symptoms of mosaic.

ON THE RECENT SWARMING OF *LOCUSTA MIGRATORIOIDES*, R. & F.

By Owen B. Lean, B.Sc., D.I.C., F.E.S.

Introduction.

I have recently been given the opportunity of analysing all the information gathered together by the Imperial Institute of Entomology concerning the outbreak of *Locusta migratorioides*, R. & F., in tropical Africa.

The object of the study was to co-ordinate the data received from all parts of the infested zones, to obtain a general picture of the invasion, and more especially to see what indications exist of the cause and source, or sources, of the original swarming. This summary does not pretend to be a complete account of the invasion. It has been compiled with the idea of giving some assistance to future investigations, in indicating the gaps that need to be filled in and the most promising lines of study.

Reports have been received from most of the infested countries, though little or nothing has come from Portuguese Guinea, Liberia, Ivory Coast, French Cameroons, Ubangi Shari, French Tchad, Belgian Congo or Abyssinia. It has been most difficult to determine to what species of locusts many of these reports refer. Identification has been reliable in the British colonies with very few exceptions: *i.e.*, Nigerian Chad, 1929; a few swarms in N.W. Nigeria, August to December 1929; and a small

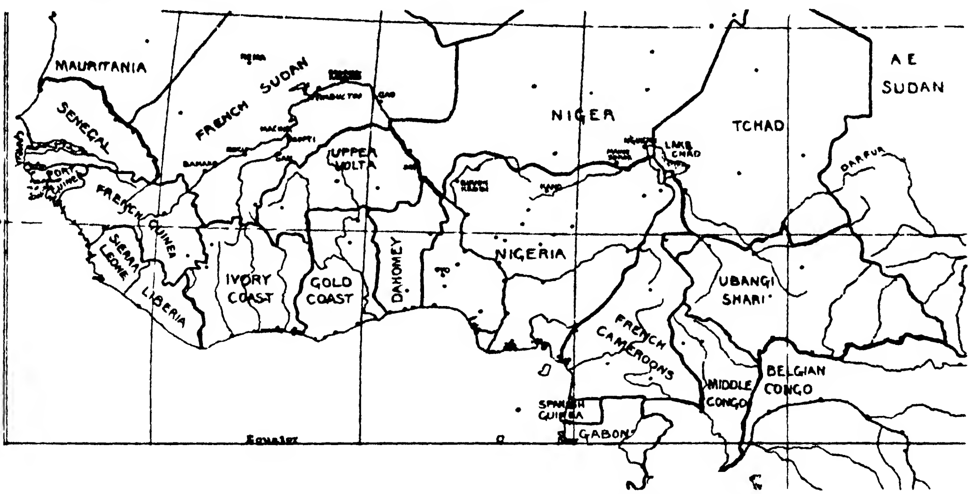

Fig. 1. Sketch map of West and Central Africa.

percentage of the swarms in the Sudan. Identification is less satisfactory, however, in the French colonies, where so far as we know, only a few specimens have been identified. Specimens of *migratorioides* have been received from Dahomey (July, October, November, December, 1930, and January 1931), and specimens from near Timbuctoo (July 1928) have been described and are identified as *migratorioides*. Specimens from French Guinea have also been determined (Chevalier, 1931). Specimens of the same species have also been received from the Belgian Congo (December 1930 and March 1931). There can be little doubt that most of the swarms in French West and Equatorial Africa south of Lat. 15°N., since July 1928, were of *migratorioides*. Those reported further north, *e.g.*, from Mauretania and Northern Niger, were more probably *Schistocerca gregaria*, Forsk.

Outline of the Infestation.

For convenience the infestation has been divided provisionally into nine periods, periods of breeding more or less alternating with periods of migration.

Period I. June—July 1928 (fig. 2).

There was an outbreak of unidentified hoppers in the Circle San, on the river Bani east of Segu, during the second quarter of the year (probably about June) ; they were

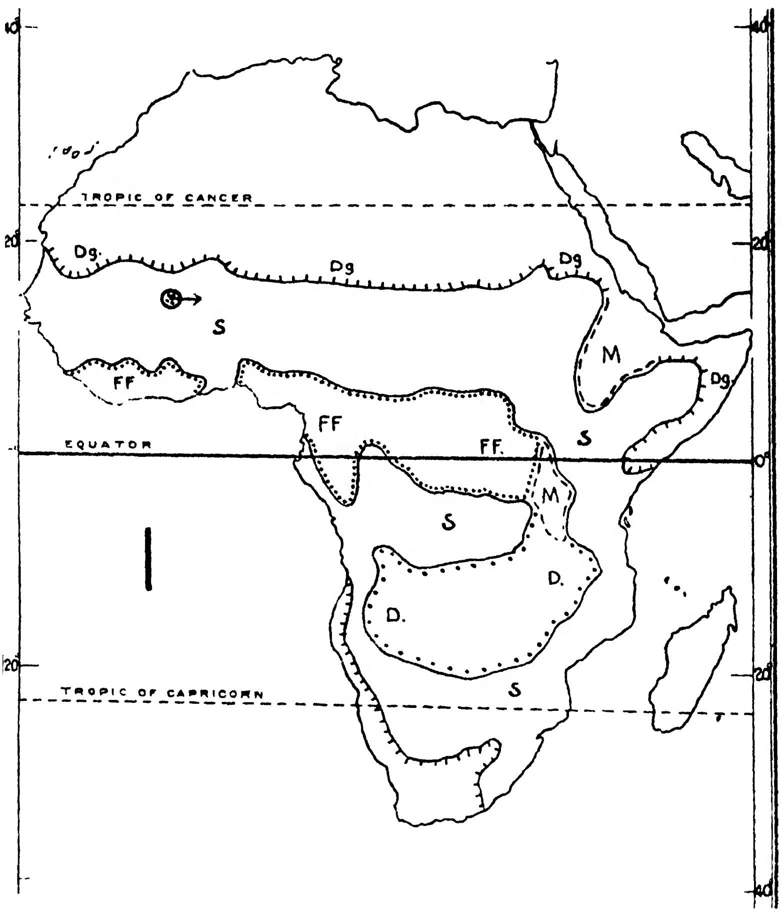

Fig. 2. Map of the first period of the outbreak, June-July 1928, showing the vegetation areas (after Schantz). *Dg*, desert shrub ; *S*, savannah ; *M*, mountain grass ; *FF*, tropical rain forest ; *D*, dry forest. On the maps for the following periods only the boundaries of vegetation areas are shown. Areas where breeding has taken place are dotted and encircled, where breeding has probably occurred are less heavily dotted. Directions of main migrations are indicated by arrows ; doubtful records by dotted arrows. Crosses denote records of swarms circling or migrating in an unknown direction.

reported in the south of the Circle Macina (60 miles to the north) by the beginning of July ; they became adult towards the end of July and migrated apparently mainly eastward.

Specimens taken from a swarm flying west to east in the Circle Gourma-Rharous, near Timbuctoo, on 28th July were identified as *migratorioides*, which indicates that the hoppers were of this species also. No parent flights had been seen in the San area before the appearance of the hoppers, but it should be noted that in July there were swarms of *Schistocerca gregaria* not very far distant, *e.g.*, Nema (230 miles N.W. of Macina).

Period II. August 1928—March 1929 (fig. 3).

There is very little to indicate what became of the above F.1 adult swarms.

(*a*) Most of them appear to have flown east as far as Long. 0° and then turned back westwards when the wind changed in November. In November swarms were flying to the S.W. in south-west French Sudan. A swarm had reached western

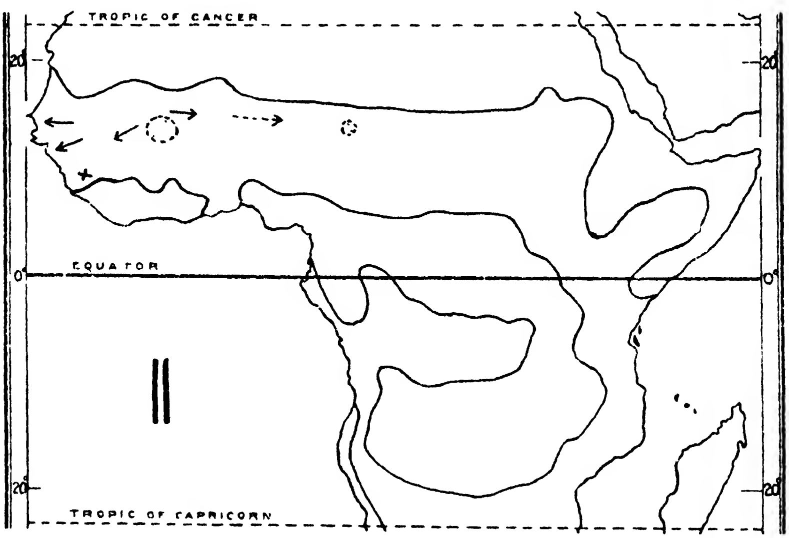

Fig. 3. Map of the second period, August 1928 - March 1929.

Senegal from the east by January, and in February they penetrated into Portuguese Guinea. They were reported in French Guinea and Sierra Leone in March. It is probable that breeding occurred during the period and that the adults that reached the west coast belonged to the F.2 generation.

(*b*) A few early matured swarms probably penetrated much further east.

Period III. April—June 1929 (fig. 4).

(*a*) The swarms that reached Sierra Leone from the north-east were mature in April and oviposited. Hoppers were found in May and June. The new generation of adults (F.3) returned flying north-east in June, and there is little trace of their movements.

(*b*) Swarms were observed in Nigerian Chad at the end of this period (June). The origin of these swarms is obscure, but they were possibly derived from the adults bred during period I (see period II, *b*), with at least one intermediate generation. Alternately they originated from the solitary phase in Chad.

(*c*) Swarms were observed in the Upper Volta.

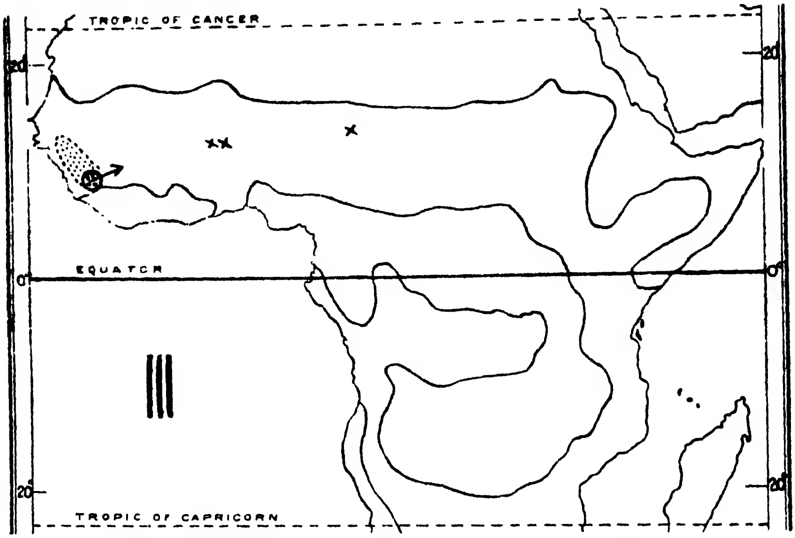

Fig. 4. Map of the third period, April - June 1929.

Period IV. July—September 1929 (fig. 5).

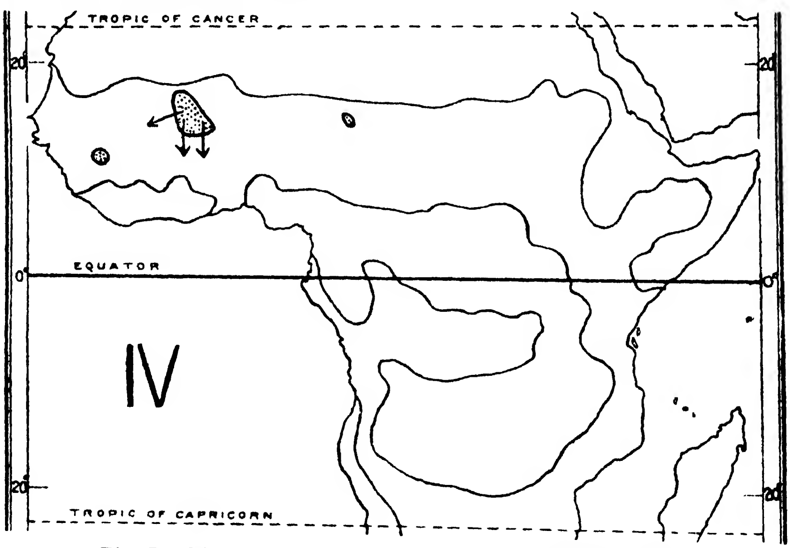

Fig. 5. Map of the fourth period, July - September 1929.

(*a*) In July extensive oviposition apparently occurred in the Upper Volta and southern French Sudan near Mopti. These swarms were probably derived from period III, *a* and *c*.

(*b*) Hoppers were found in Nigerian Chad in July and August. The resulting adults have not been traced (see period V, *c*).

(*c*) Hoppers were present in French Guinea, north of Sierra Leone (Chevalier, 1931).

Period V. October 1929—March 1930 (fig. 6).

(*a*) During this period the Gold Coast was invaded extensively from the north (October and November), the Upper Volta from the west and north-east (October

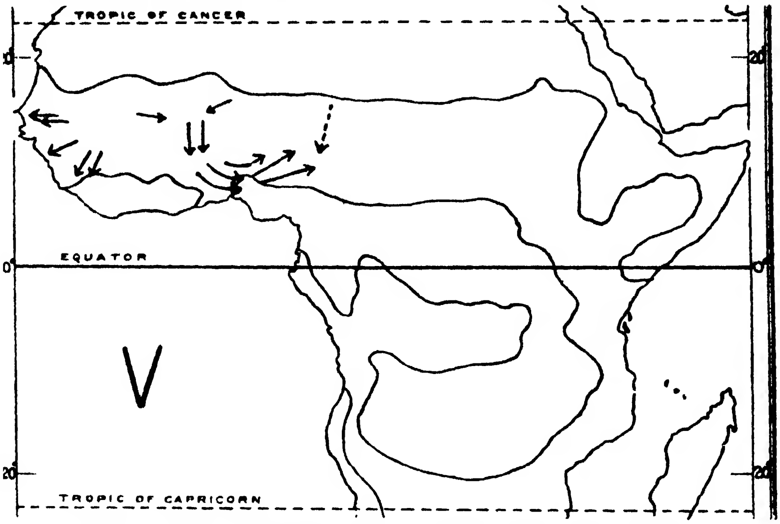

Fig. 6. Map of the fifth period, October 1929 - March 1930.

and November), and the Gambia (November) and Portuguese Guinea (December) from the east. In December and January, Sierra Leone was invaded from the north. All these invading swarms were probably the F.4 adults derived from the breeding in period IV, *a* and *c*.

(*b*) Most of the swarms in the Gold Coast seem to have moved south-east into Dahomey and then north-east to infest Nigeria (December and January).

(*c*) In February many swarms were reported in the British Cameroons, and it is probable that these came from the north-east and may be the F.4 adults bred in Chad (period IV, *b*).

Period VI. April—July 1930 (fig. 7).

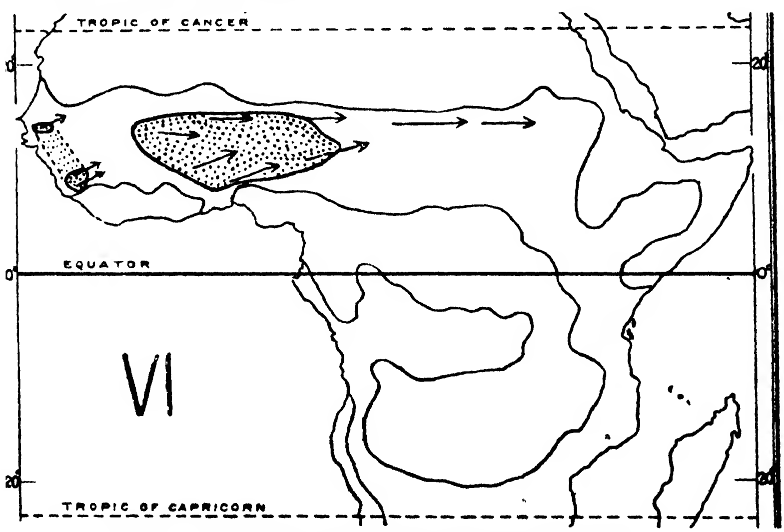

Fig. 7. Map of the sixth period, April - July 1930.

Breeding on a very large scale occurred in the Gambia, French Guinea, Sierra Leone, Upper Volta, north Gold Coast, French Niger, Dahomey, Nigeria, and probably in other areas also. The resulting adult swarms (F.5) flew off mainly in a north-east and easterly direction. Those from the Upper Volta area, where breeding probably began a little before April, entered north-east Nigeria in vast numbers in May.

Period VII. July—December 1930 (fig. 8).

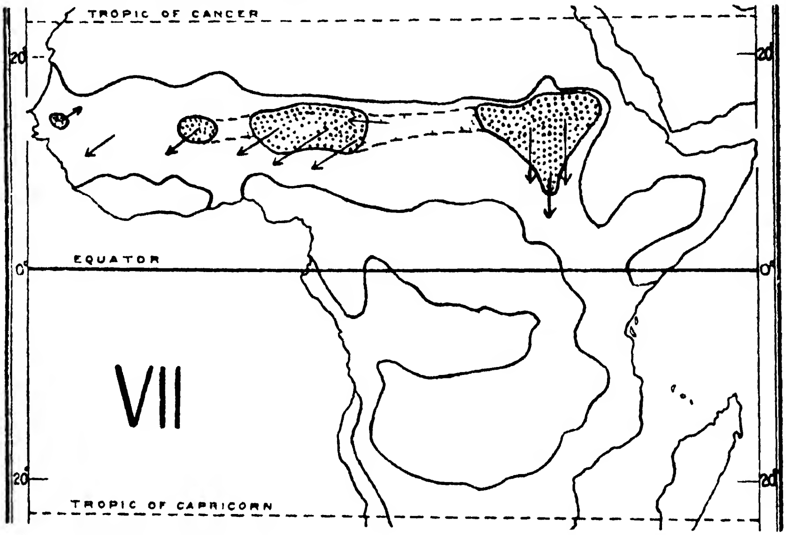

Fig. 8. Map of the seventh period, July - December 1930.

Northern Gold Coast, southern Upper Volta, north-eastern Nigeria—especially Chad—and the Anglo-Egyptian Sudan had a big invasion of hoppers (the progeny

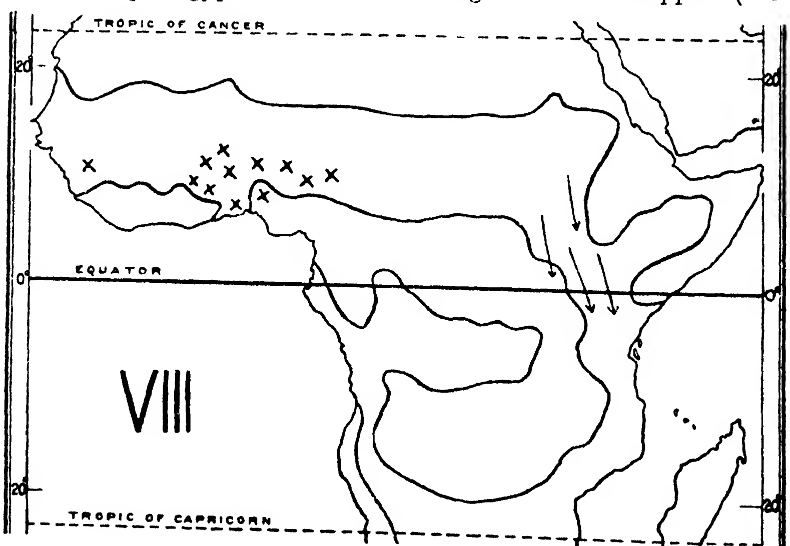

Fig. 9. Map of the eighth period, January - March 1931.

of the F.5 adults) ; it is also known that French Tchad was heavily infested, and the breeding area was probably continuous from Long. 3°W.—36°E. Adults (F.6) bred from the hoppers in the Upper Volta, Gold Coast, Dahomey, Nigeria and Tchad, migrated generally to the south-west. Those bred in the Nile valley of the Sudan moved south.

Period VIII. January—March 1931 (fig. 9).

(*a*) Swarms were circling in the middle belt of the Gold Coast, Dahomey and Nigeria.

(*b*) The swarms from the Sudan had moved south into Uganda, Tanganyika and Kenya, touching north-eastern Belgian Congo.

Period IX. Commencing March 1931.

Breeding has already been reported from the Gold Coast, Nigeria, northern Tanganyika and south-western Kenya. The next generation of adults will belong to the F.7 generation.

Character of the Country invaded.

The band of country extending from the Gambia to the Nile Valley in the Sudan, and from there southward through Uganda and Western Kenya to Tanganyika, which has been covered by the flights of *migratorioides*, corresponds roughly with the belts of the following types of vegetation, as classified by Shantz (1923, see fig. 2).

(*a*) High grass—low tree savannah.
(*b*) Acacia—tall grass savannah.
(*c*) Acacia—desert grass savannah.

The flights in the main have avoided the tropical rain forests, though these are sometimes visited during the dry season, and at the other extreme there is no evidence of their having penetrated into desert shrub. There is a broad belt of the " high grass—low tree savannah " across the south of the Congo basin. We do not know whether this has been infested, but it should prove suitable for *migratorioides*, if the swarms once reach it. There is a specimen in the British Museum collection taken about 1876 at Kilimba in southern Belgian Congo.

Breeding has occurred throughout the above belt with a tendency for the areas adjoining rivers and lakes to be most heavily infested. The swarms oviposit wherever they happen to be when sexually mature, though the female normally selects light soil for actual oviposition.

Breeding Seasons.

Normally there appear to be two breeding seasons a year. The first commences with the first rains and the second towards the end of the wet season, the adults appearing after the last rains. This normally gives a longer period through the dry season between the two breeding seasons than through the wet season, when the adults become sexually mature within quite a short period. Therefore the dry season apparently causes an adult diapause. It is not known whether this diapause can be broken by moist conditions, allowing three annual generations. There is no evidence of a diapause in the egg stage.

There is no evidence to show how many times a female may lay in the field, but Johnston & Maxwell-Darling (1931) have found that in a cage she may lay eleven times during a period of 30 days.

Owing to the great variations in the duration of the egg and hopper stages, as well as to the intervals between the various ovipositions by swarms of the same generation, not only in one locality but under different climatic conditions, during the course of the invasion one generation tends to overlap the next and the breeding seasons tend to become continuous. Thus in Bornu, Nigeria, breeding was practically continuous from May until November 1930, and in the Gambia hoppers were present from April to August 1930.

There are no records of the effects that submersion has upon the eggs in the tropics, and this may be an important point in connection with the development of the swarming phase.

A summary of the breeding seasons in relation to the rainy seasons is given in Table I. In the region of Lake Victoria there is no regular break of the rains, and it is interesting to note that breeding has taken place there at the same time as in West Africa. It will be important to see whether the adult diapause occurs in this region or whether there are more than the usual two generations.

TABLE I.

Breeding Seasons in relation to Rainy Seasons.

Period	Year	Country	Zone	Time of oviposition	First rains	Last rains	Whether 1st or 2nd annual generation	Generation produced
I	1928	Fr. Sudan	San, Macina	? June	May	Oct.	1	F. 1
III	1929	S. Leone	North	April	March	Oct.	1	F. 3
V	1929	U. Volta	Central	July	April	Oct.	2	F. 4
		Nigeria	Chad	July	June	Sept.	2	F. 4
VI	1930	Gambia	Upper river	April	May	Oct.	1	F. 5
		S. Leone		May	March	Oct.	1	F. 5
		Gold Coast	N.W.	May	April	Oct.	1	F. 5
		Nigeria	Oyo	April	March	Nov.	1	F. 5
			Niger Prov.	May	April	Oct.	1	F. 5
			Kano	June	May	Oct.	1	F. 5
VII	1930	Dahomey	N.	July	March	Oct.	2	F. 6
		Nigeria	Chad	July	June	Sept.	2	F. 6
			Kano	Sept.	May	Oct.	2	F. 6
			Niger Prov.	Oct.	April	Oct.	2	F. 6
		A. E. Sudan	El Obeid	July	May	Oct.	2	F. 6
IX	1931	Nigeria	Central		March	Nov.	1	F. 7
		Kenya	S.W.	March	—	—	1	F. 7
		Tanganyika	N.	March	—	—	1	F. 7

Direction of Migrations.

Although the flights of individual swarms are by no means always with the wind, Table II shows that the main migrations do seem to be affected by, and agree with, the prevailing winds.

The wind directions have been taken from the official records at the Meteorological Office and from Hubert (1916, 1926). The direction of the wind is given conversely to the usual practice to show the direction in which the swarm is being driven.

Swarms also tend to follow river courses.

TABLE II.

Main Migrations and Prevailing Winds.

Period	Date	Country	Zone	Direction of flight, to	Prevailing wind, to
	1928				
I	July	Fr. Sudan	Macina	E.	E.N.E.
II	Nov.	Fr. Sudan	S.W.	S.W.	S.W.
	1929				
	Jan.	Senegal		W.	S.W.
	Feb.	Port. Guinea	E.	W.	S.W.
III	Apr.	S. Leone		S.W.	S.W.
	June	S. Leone		N.E.	N.E.
V	Nov.	Gambia		W.	W.
	Dec.	Port. Guinea		W.	S.W.
	Dec.	S. Leone		S.W.	S.W.
	Oct.-Nov.	U. Volta	S.	S.	N.E. then S.W.
	Dec.	Dahomey	S.	S.E.	S.W.
	1930				
	Jan.–March	Nigeria	S.W.	N.E.	N.E.
	Feb.	Br. Cameroons		? S.	N.E.
VI	July	Gambia		E.	E.N.E.
	June, July	S. Leone		N.E.	N.E.
	May–July	Nigeria		E.N.E.	N.E.
	May–July	U. Volta		E.N.E.	E.N.E.
VII	Aug.	Gambia		N.E.	S.E.
	Aug.	Nigeria		N.E.	N.E.
	Oct.	Nigeria		S.W.	S.W.
	Nov.	Gold Coast	N.	S.W.	S.W.
	Nov.	A. E. Sudan		S.	S.W.
	1931				
VIII	Jan.	Uganda		S.	N.

The Solitary Phase.

Isolated individuals showing characteristics of the phase *solitaria* have been encountered amongst the hopper bands in various parts of West Africa. Almost all of these probably represent the phase *dissocians*, and their presence has been most noticeable in areas where control measures have been carried out.

Most interesting observations are described by Johnston & Maxwell-Darling (1931) on the breeding in the Sudan towards the northern limit of the area covered by the swarms, which limit, as we have seen, corresponds closely with the transition from the "acacia-desert grass savannah" plant association to the "desert shrub-desert grass" association. Locusts bred in this area from the true *migratorioides* that migrated from the west did not attain the full *migratorioides* phase, but developed into something much closer to *migratoria*.

Phase *solitaria* (*danica*) is very widely distributed and is found throughout Africa, except in the dense forests and waterless deserts (Uvarov, 1928). Little, however,

is known of its life-history. Johnston and Maxwell-Darling (1931) give some figures for the duration of the stages in cage experiments and state that in 1926 only one generation was produced in the field, the governing factor being the continuance of fresh grass. The period of diapause is passed as an adult during the dry season.

Food-plants.

The adults of *migratorioides* feed almost entirely on plants of the order Gramineae, especially maize, guinea corn, millet, rice and sugar-cane of the cultivated crops. During the dry season they occasionally attack coconut and oil palms, plantains, pineapple, sisal, etc., in search of water rather than food. They seem to feed most when approaching maturity.

The diet of the hoppers is similarly restricted ; they attack groundnuts occasionally.

On the possible Origin of the Infestation.

It has been seen that *migratorioides* probably appeared first in central French Sudan (July 1928). If the locusts that reached Senegal and Portuguese Guinea were *migratorioides*, there can be little doubt that they and those that invaded Sierra Leone were connected with this outbreak.

It is less certain, though probable, that the locusts that appeared in Chad in June 1929 were connected with the French Sudan flights. The first matured adults from the Sudan 1928 breeding should have been able to reach Chad with the prevailing wind before it changed in October. That we have no reports of breeding in Chad in the latter part of 1928 means very little.

The only other swarms of *migratorioides* that might have developed independently are some of those that appeared in the Anglo-Egyptian Sudan during the last seven months of 1930. It is thought possible that some of the swarms travelling north in the Upper Nile Province in May may have been of this species, and if this were so, it is most unlikely that they were related to the West African outbreak. The main migration into the Sudan began at the end of June with a big invasion from the west into Darfur, and there is no doubt that these flights were connected with those on the west coast ; they were probably either the F. 5 adults from the Nigerian breeding or the progeny of some unrecorded breeding in the Colonie du Tchad, previously derived from further west, *e.g.*, Chad, F.4.

As we have seen, the solitary phase is widely distributed in Africa. It seems, however, that the swarming phase has not developed independently in a number of localites spread over a wide area of Africa, but, at the most, in three localities, and probably in one only.

1. *San—Macina, French Sudan.*

As has been described, this is the area most suspected of being the original source of the recent swarming, although the evidence is still very indefinite. The actual region where hoppers were first reported is about 200 miles up the Niger from Timbuctoo.

The whole of the Niger valley from Segu to 160 miles east of Timbuctoo undergoes vast annual inundations. The times of the flood in the different reaches of the river are peculiar and may be of importance.

Between Bamako and Segu the water is highest in September. At Mopti and between Mopti and San on the tributary river Baule, the maximum is in October. From Timbuctoo past Gao to Say the flood is in January. At the same time there is a greater annual rise at Bamako (8–9 metres) than at Timbuctoo (6 m.) or Gao (3–5 m.) (Lenfant, 1903 ; Chudeau, 1913).

In this lake district of the Niger the dry season lasts from November until the end of April, most rains fall from June to September, and July is the wettest month.

Low water is in June, during the rains and when breeding would take place (see period I), exposing vast areas of the country well suited to the breeding of the locust. It is known that the height of the flood varies greatly from year to year and that some areas are only flooded occasionally (Chevalier, 1900), so that the character and extent of the vegetation must vary similarly. Chevalier (1931) suspects an area, limited by the Sahara on the north, and by the middle Niger and Senegal rivers on the south, as being the permanent breeding-ground.

2. *Lake Chad.*

Although the present survey indicates that Chad is a temporary rather than a permanent breeding-ground, it has long been thought a possible source of locust invasions.

During a recent visit there from August to October 1930 (period VII), the solitary phase was found to be very common, but there was no evidence of any transition towards the gregarious.

On the other hand the natives of Chad declare that almost every year there are small flights of locusts away from the lake. Also, in a paper written in 1923 (Inst. Intern. Agric., 1923) it is seen that in the eastern French Niger swarms are frequent, though the identification of the locust is uncertain. They are mainly reported as coming from the east, *e.g.*, at N'Guigmi they are most numerous in November (*cf.* period VII), and many flights reach Maine-Soroa coming from Chad during the dry season.

As in the Niger lake district, the water of Lake Chad is low during the rainy season and rises and inundates the surrounding country in the dry season, high water being about January. The rains last from June to September.

3. *Sudan.*

It seems reasonable to expect that some area of the upper Nile may well possess the necessary conditions for producing the swarming phase, but there is little yet to suggest that swarming has begun independently in these parts.

4. *Senegal River.*

The possibility of flood areas along this river being permanent breeding-grounds should also not be ignored.

Previous Invasions.

Only very scanty information exists about previous outbreaks of *migratorioides* in Africa, for although there are many records of locust swarms, very few specimens have been determined.

It is obvious, however, that during the last decade of last century an infestation occurred similar in extent to the present one. It seems to have lasted at least from 1891 to 1902.

As will be seen from the following list of records extracted from the literature and from records of the specimens in the British Museum collection, there is little to show the general course of the infestation.

1891. Togo. January, March, December (Sander, 1902).
French Guinea. It is said that about this time Guinea was invaded from the north-east for several successive years.
Anglo-Egyptian Sudan. Natives recall an invasion about this time from the west.

1892. Togo. January (Sander, 1902), November, December (Baume).
Nigeria. There is a specimen in the Museum collection taken in the hinterland of Lagos about this time.
Ivory Coast. Another specimen was taken at Cape Palmas about this time.
Abyssinia. In September and October specimens were taken from localities thought to be in southern Abyssinia (Schulthess-Schindler, 1898).

1893. Togo. March and October to December (Sander, 1902; La Baume, 1910).
Sierra Leone. Specimen in the Museum taken at Freetown in November.
Gold Coast. Specimen in the Museum taken in Ashanti about this time.
Cameroons. Specimens in the Museum taken at Anibas Bay about this time.
German East Africa. September (La Baume, 1910).
In February of this year a swarm was observed 100 miles out to sea off Gorree, near Cape Verde (La Baume, 1910).

1894. Togo. March and June (La Baume, 1910).
Abyssinia. September and November (Rehn, 1901).
German East Africa. January, February, April and October (La Baume, 1910).
Nigeria. Specimen in the Museum taken at Calabar about this time.

1896. Nyasaland. Specimens in the Museum taken in June.

1897. Angola. September (Bolivar, 1908).

1898. Nigeria. Specimen in the Museum taken at Jebba about this time.

1900. Togo. May, November, December (La Baume, 1910).
Nigeria. Specimen in the Museum taken at Lagos.

1901. Nyasaland. Specimen in the Museum taken about this time.

The natives of Nigeria recall this infestation, and most parts of the country seem to have been invaded. Apart from those localities mentioned above, it is certain that the north from Birnin Kebbi to Chad was also infested.

A general invasion is also recalled in Sierra Leone.

Records of swarms in French West Africa are summarised in three publications by the International Institute of Agriculture, Rome (1916, 1923, 1926), but as the identifications are indefinite, these records are of little value. It is stated (1923) that many of the swarms between 1899 and 1902 in Senegal were of *migratorioides*.

Before this 1891–1902 outbreak there are, naturally, very few records. One specimen in the Museum collection was taken in south-eastern Belgian Congo about 1876.

The original description of *migratorioides* by Reiche & Fairmaire was from specimens collected by Ferret & Galinier in Abyssinia. These authors give an interesting account of the swarm seen on 19th May, 1842, somewhere between Gondar and Adowa in northern Abyssinia (1847, ii, pp. 495–6).

Recent Studies on the Causes of Swarming.

1. Zolotarevsky in his recent paper (1929) on *Locusta migratoria capito*, Sauss., in Madagascar, suggests conditions that may cause the transition from the solitary to the gregarious phase.

The solitary phase is found throughout the western half of the island, and the most suitable habitats exist in the west and south-west, although the swarms seem to originate in the south, where much more arid conditions obtain and where there are marked wet and dry seasons.

The theory is that during the rains the solitary individuals are scattered throughout the southern savannah, and with the coming of dry season they naturally congregate in the more humid places; consequently eggs are laid in concentrations. Furthermore, none of the eggs hatch until after the first rains, if there is the egg diapause, as is suspected. The result is a heavy concentration of hoppers that may start the transition to the gregarious phase, and this transition, once commenced, will naturally lead to swarming.

2. Olsufiev (1930), working in Russia, attacks the question from rather a different angle, *i.e.*, what conditions prevent a sufficiently heavy destruction of *migratoria* to stop the swarming phase from developing regularly.

It is pointed out that there is a very great annual variation in the height and time of the flood in many of the south Russian rivers. During the driest years the reed beds dry up and are encroached upon by the steppe; after normal flooding the reed beds return to normal. These changes of plant associations cause changes in the locality chosen by the locusts for oviposition. It has been shown that if eggs are flooded at an early stage, they do not perish, but hatch a little later than normal; if they are flooded towards the end of the embryonic development, even a short period of submersion is sufficient to destroy them.

The number of hoppers that will survive therefore depends upon: (*a*) the height at which most eggs have been laid (this varies according to the previous year's flood); (*b*) the height of the flood; (*c*) the time of the flood; (*d*) the state of embryonic development at the time of the flood.

It is pointed out that the various factors necessary for even a partial destruction of hoppers cannot coincide every year.

3. Johnston & Maxwell-Darling (1931) describe how in 1926 on the Red Sea coast an incipient swarming phase of *migratoria* was caused by unusually heavy rainfall. The luxuriant vegetation allowed the solitary phase to pass through several generations and towards the end of the rains small bands of hoppers were seen.

These studies suggest the kind of conditions that may, perhaps, be found to cause the swarming of *migratorioides* and so indicate the most hopeful lines for future work. At the present time there are too many gaps in our knowledge, not only of the biology of the locust, but of any recent peculiarities of rainfall and flooding, and the manner in which they affect the plant associations, to attempt to suggest how the present outbreak commenced. It is not known, for instance, whether regular records are taken in the upper and middle Niger, but the work of Olsufiev illustrates the value of records of the water régime in the great rivers and lakes, and it is hoped that figures for recent years may be available.

Summary and Conclusions.

The present paper attempts to summarise the information collected by the Imperial Institute of Entomology on the swarming of *migratorioides* in Africa.

It is concluded that the outbreaks in West, Central and East Africa are all interrelated and probably originated in one or at most two permanent breeding-grounds.

The area most suspected is the lake district of the middle Niger, where conditions seem suitable for the formation of the swarming phase. Lake Chad is probably a secondary rather than a permanent breeding-ground.

It is indicated that the key to the problem of the cause of the original outbreak may be found in the study of recent variations in the water régime of the River Niger.

Should these suppositions be substantiated, we are well on the way towards a solution of the problem. The ultimate control of the locusts depends not on control during the swarming periods, but upon preventing the swarming phase from developing in the permanent breeding-grounds.

It is therefore important to check and augment the records of the early swarms in West Africa and more important still, to study the behaviour of the locust, its ecology, and the water régime in the suspected areas.

In conclusion the author wishes to acknowledge the constant help and advice of Mr. B. P. Uvarov. His thanks are also due to Mr. H. B. Johnston for his permission to make use of his paper in manuscript.

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THE PSEUDOPUPA AND THE LAST LARVAL INSTAR OF *EPICAUTA ERYTHROCEPHALA*, PALL. (COL. MELOIDAE).

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The pseudopupa and last larval instar of *Epicauta erythrocephala*, Pall., have remained undescribed up to the present, although the economic importance of the insect is very great, the beetle being an important pest of many cultivated plants and its larva a parasite of locust egg-pods. These stages are, however, figured in the work of I. Portchinsky[1], published in 1914, but in the figure of the pseudopupa the stigmata on the three thoracic segments are omitted.

During investigations made in early spring (1926–1927) in the environment of Old Bukhara, I found a great quantity of the pseudopupae and larvae of the last instar of *E. erythrocephala* in the soil. In the early spring of 1929 the same instars were reared in the insectary of the Agricultural Experimental Station at Shirabudin (Old Bukhara).

Description of the Pseudopupa.

Colour varying from dark yellow to orange. Slightly curved in shape, the dorsal side convex, the ventral flattened (slightly convex on the thorax). The length is 8–12 mm., the width 5 mm., the body slightly tapering to the ends. The integument slightly striated longitudinally, as seen with a hand-lens, the striae

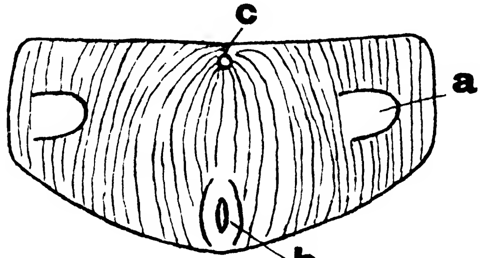

Fig 1 The 1st thoracic segment of the pseudopupa of *Epicauta erythrocephala*, seen from below : *a*, leg tubercles ; *b*, tubercle ; *c*, pit

being parallel and giving a wrinkled appearance. On the median line of the dorsal surface from the middle of the head to the middle of the last segment of the abdomen is seen a suture-like, slightly convex stripe, which is indistinct on the last segment.

The head small, up to 2–5 mm. in width. The furrow between the head and thorax on the dorsal side only slightly marked, but very deep on the ventral side. On the face a triangular stripe with its apex directed backwards, the angles of the triangle being obtuse (in particular the upper one). From the middle of the triangle ridges radiate in all directions, crossing the outlines of the triangle. The labrum is small and does not cover the tips of the mandibles. At the base of each mandible a distinct antennal tubercle ; posteriorly to each tubercle a black eye-spot. The mandibles

large, without teeth ; under the mandibles two maxillary tubercles and one labial. At the top of the labial tubercle, instead ot labial palpi there are two small tubercles. The tips of the antennae, mandibles, maxillae and labiae often black.

The 1st thoracic segment wider than the 2nd and 3rd, and on its dorsal surface, at each side of the suture-like stripe, a conical pit ; on each side of the 2nd thoracic segment, near the anterior margin, a large stigma ; on the 3rd thoracic segment, at the same place, a very small stigma. On the ventral surface of the 1st thoracic segment a small tubercle, and on its tip a longitudinal depression. In front of this tubercle a small, but quite deep pit (fig. 1). On the sides of each thoracic sternite are small leg-tubercles. The pleurites of the thorax are not conspicuous.

The number of abdominal segments is nine, and each (except the 9th) bears stigmata, which are smaller than those on the 2nd thoracic segment, but larger than those on the 3rd. The arrangement of the stigmata is of the holopneustic type, their colour being dark, nearly black.

In the middle of the 9th segment, posteriorly there is a straight transverse anal opening (blind), above and below which is a lip-like elevation, the inferior elevation bearing a median depression. On the ventral surface of the 9th segment, under the anal opening, is a small rounded depression followed by a small semi-lunar furrow, with its convex side directed forward. Behind this impression is a short straight furrow, which does not reach the inferior lip-like area under the anal opening (fig. 2).

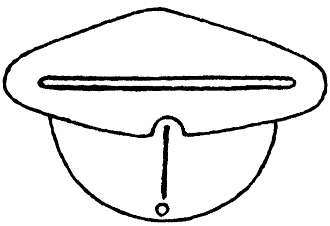

Fig. 2. The end of the 9th abdominal segment of the pseudopupa of *E erythrocephala*

The last larval instar.

Fabre[3] called this instar the 3rd larva ; Riley[2], the scolytoid larva ; and Portchinsky[1], the 4th larva. Uvarov[4] has pointed out Portchinsky's mistake, his 3rd larva being the 2nd larva shortly before the moult into the 3rd instar. The 2nd larva immediately after the moult from the 1st instar differs greatly from the 2nd larva shortly before its moult into the 3rd instar.

The larva is dirty white or light yellowish in colour, and horseshoe-shaped. Length (when straightened) 8–12 mm., width 7 mm. ; the body slightly tapering behind. The dorsal surface convex, the ventral very slightly convex (the thorax slightly more so than the abdomen). The skin delicately sculptured—wrinkled, the wrinkles very finely punctured. All the body is covered with very short, sparse, light-coloured hairs.

The head concolorous, smooth, shining, a little narrower than the body, 2–3 mm. wide. The furrow on the face of the pseudopupa is also conspicuous on that of the last instar larva and is surrounded by a low elevation. On each side of the furrow, from the base of the antenna and mandible, there are obliquely longitudinal impressions, which do not reach the upper angle of the furrow. The labium is small and does not reach the tips of the mandibles. The transverse suture at the base of the labium

very conspicuous ; at the external margin of the labium a thick brush of very short red hairs. The antennal tubercles broad and short, white at the base and dark at the tip ; behind the base of each tubercle a small, delicately pigmented eye-spot. Mandibles brown, black at the tips, without teeth. Maxillae and labium white, covered with sparse, coarse reddish bristles. Labial palpi short, biarticulate ; the 2nd segment longer and thinner than the 1st. Maxillary palpi also short, 3-segmented ; the 3rd segment is long and thin (fig. 3).

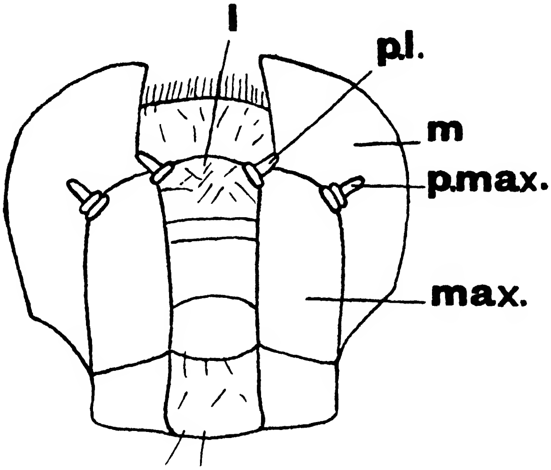

Fig 3. The mouth-parts of the last larval instar of *E. erythrocephala* : *l*, labrum ; *p.l.*, labial palpi ; *m*, mandibles ; *max.*, maxillae ; *p. max.*, maxillary palpi.

The 1st thoracic segment wider than the 2nd and 3rd. The 1st tergite of the thorax with yellowish white shield. In the middle of the 1st and 2nd thoracic sternites a well developed longitudinal suture, which continues on the base of the 1st sternite and there joins a triangular depression. Anterior to this depression is a tubercle bearing a furrow, as described for the pseudopupa (fig. 4). On the anterior

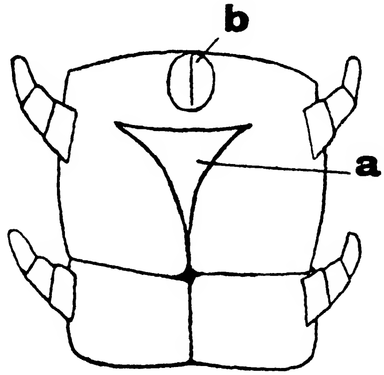

Fig. 4. The 1st and 2nd thoracic segments of the last larval instar of *E. erythrocephala* : *a*, triangular depression ; *b*, tubercle.

margin of the 2nd thoracic segment there are two large stigmata, and two small ones on the 3rd segment. The legs are short, without claws, thickly covered with coarse reddish bristles and spines on the inner surface; on the outer surface the bristles are sparser. At the tips of the legs there are very dense rings of bristles.

The number of the abdominal segments is 9, each (except the 9th) bearing stigmata. The anal opening is transverse.

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THE RELATIONSHIP BETWEEN *GLOSSINA MORSITANS* AND THE EVAPORATION RATE.

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In a recent paper by the writer (Bull. Ent. Res., xxi, 1930, pp. 201–256) it was shown that the apparent fly density varied according to season. It has now been found that these seasonal variations in the fly density can be correlated with the evaporation rate.

The accompanying graph shows the mean monthly evaporation rate, and the mean monthly apparent fly density. The evaporation rate figures have been obtained from a Livingston atmometer at the Kikori Entomological Station. The fly figures have been taken from the North-East Kikori Round, because this fly-round is not subjected to large game movements and hence is considered to be the best for demonstrating the correlation between fly density and season.

The graph deals with a period of eighteen months, and it is clear that a relationship does exist between the two curves.

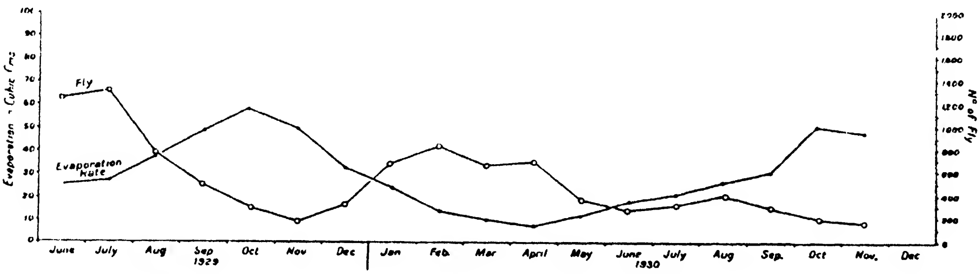

Fig. 1. A comparison between the mean monthly evaporation rate and the mean monthly fly density.—N.E. Kikori round.

In June and July 1929, the fly density was at its maximum. Hence it is reasonable to postulate that, at this time, the evaporation rate was suited to the requirements of the fly community. Let it be assumed that an evaporation rate of about 25 cc. a day affords an optimum condition for fly. It will be seen that, as the evaporation rate increased above this figure, so the fly density decreased. In October 1929 the evaporation rate reached its maximum of nearly 60 cc. a day. Hence this month can be considered to have afforded the worst conditions for the fly community, considering the evaporation rate. One would hardly expect this adverse factor to have an immediate effect upon the fly community ; however, by the next month, the fly density had reached a minimum. The evaporation rate now fell, and with the moister conditions of the atmosphere ensuing, the fly density increased. By January 1930, the evaporation rate had dropped to about 25 cc. a day—the rate assumed to afford the optimum condition for fly. Yet again, after a lag of a month, the fly density reached its second maximum point.

It has been suggested that, if the evaporation rate reaches an extremely high figure, its effects will be inimical to fly (*vide* October 1929) ; similarly, it is suggested that, if the evaporation rate falls below a certain point, it may also produce conditions adverse to fly.

The rains occurring in the early part of 1930 were most abnormally heavy. It will be seen from the graph that in April the evaporation rate fell to about 7 cc. a day, and that after the lag of a month, the fly density fell considerably. This decrease in fly numbers does not occur in years of normal rainfall.

After this the evaporation rate rose till it reached the alleged optimum for fly between July and August 1930. In August the fly density reached its third maximum point. The evaporation rate then steadily rose above the 25 cc. mark, and, as in 1929, the fly density steadily decreased.

From the foregoing it is clear that, during the period under consideration, there was a distinct correlation between the seasonal fluctuations in apparent fly density and the evaporation rate.

The evaporation rate is, of course, itself correlated with temperature, wind and humidity.

It has been noticed that, some weeks after the bush fires, the fly density drops considerably (Nash, *l.c.*). It has also been suggested that this delayed drop may either be due to the destruction of puparia (resulting in a lack of young fly to take the place of those that are dying), or to the altered environment which is no longer suitable to the fly community. The evaporation rate rises considerably when the vegetation has been burnt, hence the environment is probably distinctly less suitable to fly after the fires, and the delayed drop in density that occurs may be due to this factor.

PARASITES AND HYPERPARASITES OF THE EGG-PODS OF INJURIOUS LOCUSTS (ACRIDODEA) OF TURKESTAN.

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The following brief contribution summarises a part of the contents of an extensive Russian report on parasites of the egg-pods of some Turkestan Acridodea,* studied by the writer while on the staff of the Middle-Asian Institute of Plant Protection (Tashkent, U.S.S.R.), in the years 1927–30.

The writer is specially indebted to Mr. V. I. Plotnikov, Director of the Institute, under whose supervision the work was done, and who kindly identified the Acridian hosts; and for the identification of the parasites reared, to Messrs. A. A. Ogloblin, Santa-Anna (SCELIONIDAE), S. J. Paramonov, Kiev (BOMBYLIIDAE), B. B. Rohdendorf, Leningrad (TACHINIDAE) and B. S. Kuzin, Moscow (MELOIDAE).† The author's thanks are due also to Mr. B. P. Uvarov, for his kind assistance in the publication of this note.

The list of the hosts studied includes nine species. Their parasites can be listed as follows:

1. Dociostaurus maroccanus, Thnb.

1. *Mylabris frolovi*, Germ.
2. *Mylabris deserta*, Sum.
3. *Mylabris tekkensis*, Heyd.
4. *Mylabris scabiosae scabiosae*, Ol.
5. *Mylabris atrata*, Pall.
6. *Trichodes*, 2 spp.
7. *Callistoma desertorum*, Lw.
8. *Anthrax oophagus*, Par.
9. *Hemipenthes (Thyridanthrax) pallidipennis*, Par.

2. Calliptamus italicus, L.

1. *Epicauta erythrocephala*, Pall.
2. *Mylabris frolovi*, Germ.
3. *Mylabris 4-punctata*, L.
4. *Cytherea setosa*, Par.
5. *Anastoechus nitidulus*, F., var.
6. *Anthrax jazykovi*, Par.

3. Calliptamus turanicus, Tarb.

1. *Mylabris frolovi*, Germ.
2. *Callistoma desertorum*, Lw.
3. *Cytherea setosa*, Par.
4. *Anastoechus nitidulus*, F., var.
5. *Anthrax oophagus*, Par.

* The first part of this work, dealing with Coleopterous parasites, will be published as Bulletin No. 23 of the Middle-Asian Institute of Plant Protection, Tashkent, 1931

† Some species of *Mylabris* were determined by the writer.

4. Locusta migratoria, L.

1. *Epicauta erythrocephala*, Pall.
2. *Anastoechus baigakumensis*, Par.
3. *Oophagomyia plotnikovi*, Rohd.
4. *Scelio nikolskyi*, A. Ogl.

5. Schistocerca gregaria, Forsk.

1. *Epicauta erythrocephala*, Pall.
2. *Callistoma desertorum*, Lw.
3. *Cytherea setosa*, Par.
4. *Oophagomyia plotnikovi*, Rohd.
5. *Stomatorhina lunata*, Fabr.

6. Ramburiella turcomana, F. W.

1. *Mylabris deserta*, Sum.
2. *Mylabris scabiosae scabiosae*, Ol.
3. *Mylabris biguttata*, Gebl.
4. *Trichodes* sp.
5. *Callistoma desertorum*, Lw.
6. *Anthrax oophagus*, Par.
7. *Anthrax monachus*, Sack.

7. Dociostaurus kraussi, Ing.

1. *Mylabris frolovi*, Germ.
2. *Mylabris deserta*, Sum.
3. *Mylabris scabiosae scabiosae*, Ol.
4. *Trichodes* sp.
5. *Callistoma desertorum*, Lw.
6. *Anthrax oophagus*, Par.

8. Dociostaurus albicornis turcmenus, Uv.

1. *Mylabris tekkensis*, Heyd.
2. *Mylabris scabiosae scabiosae*, Ol.
3. *Callistoma desertorum*, Lw.

9. Dociostaurus crucigerus tartarus, Stschelk.

1. *Mylabris scabiosae scabiosae*, Ol.
2. *Callistoma desertorum*, Lw.
3. *Anthrax oophagus*, Par., var. *parva*, Par.

The biological data obtained are shortly summarised in the following systematic list of the 21 species of parasites reared.

COLEOPTERA.

Family Meloidae.

1. Epicauta erythrocephala, Pall.

This blister-beetle is the most valuable Coleopterous parasite of the egg-pods of *Calliptamus italicus* and *Locusta migratoria*, and occasionally infests those of *Schistocerca gregaria*. The percentage of egg-pods of *C. italicus* parasitised by larvae of *E. erythrocephala* ranges from 1·3 to 29·3, an average of 10 per cent. being annually destroyed.

In Turkestan it is evidently mesophilous, and seems to be strictly localised on cultivated lands, where the beetles frequently devastate lucerne fields.

Oviposition takes place from the end of June until mid-August. The eggs, 35–60 in number, are laid in small cavities dug by the female in the damp soil of irrigated fields. The construction of this egg-hole shows many interesting features, and is as complicated as that of the American representatives of this genus and the nearly allied genus *Macrobasis*, Lec. (*cf.* Milliken, 1921).

The primary larva (triungulin) hatches after 22–38 days, searches for an egg-pod and enters it. The development within the pod takes about 5 weeks. The feeding larva moults four times and passes through five successive instars (triungulin, and four instars of the " second larva " state). In September and October the fifth stage larvae leave the empty egg-pods and bury themselves in the surrounding soil, where they construct small ellipsoidal hibernating holes. In this hole the larva moults once more, transforming into a hard-bodied motionless coarctate larva or pseudopupa,* which hibernates.

In the spring (April and May) a further moult takes place; the new active (third prepupal or posthypnodial) larval stage† crawls out of the cast skin of the coarctate stage into the soil and, after some wandering, constructs a new hollow, in which it pupates. The duration of the prepupal larval stage is 12–37 days according to the soil temperature. No feeding takes place throughout this stage. The adults emerge from the end of May until July.

The resting stage (pseudopupa) can be repeated during an individual development two or three times (the same phenomenon was observed by Milliken (1921) in some American species of *Epicauta*). A diapause, lasting many years, of some of the pseudopupae of each brood was also regularly noticed.

2. Mylabris frolovi, Germ.

In the egg-pods of *Dociostaurus maroccanus*, *D. kraussi*, *Calliptamus italicus* and *C. turanicus*, the percentage of parasitised pods is not so high as in the preceding species.

The adults are common in semi-desert areas and feed on flowers of various Leguminosae: *Alhagi camelorum*, *Sophora alopecuroides*, *S. pachycarpa* and especially *Psoralea drupacea*. The emergence of the beetles takes place from the end of May, and they persist until the end of June or beginning of July. The large, yellow or orange eggs, fifty on the average, are laid in egg-holes excavated by the females in dry sunny places, such as roadsides, small mounds, etc. The development of the larvae in the egg-pods occurs in July and August. The 5th stage larvae also leave the egg-pods for hibernation and transform in the soil into dark brown, rigid pseudopupae. The spring development is similar to that of *E. erythrocephala*.

3. Mylabris deserta, Sum. (*M. frolovi* morpha *deserta*, Sum. 1929; ? *M. königi*, Dokht. 1889.)

This species is closely related to *M. frolovi* and seems to have been often confused with it. *M. deserta* develops in the egg-pods of *Dociostaurus maroccanus*, *D. kraussi*, *Ramburiella turcomana*, etc., and often infests up to 45 per cent. of those of *D. maroccanus*. It inhabits desert or steppe localities and is definitely a spring

* The figure of the pseudopupa of *E. erythrocephala*, given by Portchinski (1914), is incorrect.

† Portchinski's (1914) figure of this stage is wrong; the larva figured is probably that of *M. 4-punctata* (5th instar).

species. The adults appear very early in April and occur abundantly until mid-May; they feed on flowers of many plants, *e.g.*, *Trigonella grandiflora*, *Papaver pavoninum*, *Malcolmia* spp., and others.

The small very numerous white eggs (400–500 in number) are laid in the localities frequented by the beetles and locusts. The very small yellow triungulins are the earliest of the parasitic larvae infesting the locust egg-pods; development within the pods occurs during June and July. The 5th stage does not leave the empty egg-pod to transform into the pseudopupa. Corresponding to its protected position, the pseudopupa is much more delicate and light-coloured than that of *M. frolovi*. The spring development is relatively very rapid.

4. **Mylabris tekkensis,** Heyd.

Develops in the egg-pods of *Dociostaurus maroccanus* and probably other species of *Dociostaurus*, as many as 10–20 per cent. of them being parasitised.

Inhabits the same desert areas infested by the Moroccan locust, like the preceding species, but develops later in the summer. The beetles appear at the end of May and are common, especially on blossoms of *Psoralea drupacea*, until July. Each female produces about 80 white elongate eggs. The triungulins are frequently observed running on the surface of the soil of infested areas, searching for egg-pods. The adult (5th stage) larva leaves the pod and hibernates in the soil.

5. **Mylabris scabiosae scabiosae,** Ol.

Develops in the egg-pods of *D. maroccanus*, *D. kraussi*, *D. crucigerus tartarus*, *Ramburiella turcomana*, and probably other xerophilous Acridodea. Infests a high percentage of the pods (up to 25–40 per cent.) and may be considered one of the important parasites of the Moroccan locust.

The bionomics of this species resemble very closely those of *M. tekkensis*. The eggs are smaller, about 100–120 in number. The adult larva rests in the empty pod, where it transforms into a delicate pseudopupa and pupates after hibernation and two further moults.

6. **Mylabris 4-punctata,** L.

Infests egg-pods of *Calliptamus italicus*. Bionomically this species seems to be very similar to *M. frolovi*, but is decidedly more hygrophilous. It often co-operates with the last-named species in the destruction of eggs of *C. italicus*. The eggs are very large and less numerous (about 40–50) than in the majority of the other species. The triungulins are correspondingly very large.

7. **Mylabris atrata,** Pall.*

Triungulins of this species reared *ex ovo*, fed and successfully developed on eggs of *D. maroccanus*. The actual host of the species is unknown. The egg-production is low (35–40 eggs), and oviposition takes place in June. The beetles feed on flowers of cultivated flax (*Linum usitatissimum*, L.) and certain weeds.

8. **Mylabris biguttata,** Gebl.*

Larvae were found in the egg-pods of *Ramburiella turcomana* from the Katta-Kurgan district, valley of the Zerafshan River. More prolific than *M. atrata*, laying as many as 88 eggs.

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* Modern taxonomists generally treat *M. atrata* and *M biguttata* as varieties of the same species, *M. polymorpha*, Pall This is, however, incorrect, the primary larvae of the two recorded species being very distinct

Family CLERIDAE.

9. Trichodes sp. 1. (?**turkestanicus,** Kr.).

The characteristic pink larvae of a *Trichodes* were found in small numbers in egg-pods of *Ramburiella turcomana* and *Dociostaurus kraussi* in the steppes of the Katta-Kurgan district. Adults not yet hatched.

10. Trichodes sp. 2.

Large, hairy larvae of a second species of this genus (probably *T. spectabilis*, Kr.) are occasionally found in egg-pods of *D. maroccanus* in the Dalversin Steppe. Adults not reared.

DIPTERA.

Family BOMBYLIIDAE.

11. Callistoma desertorum, Lw.

This large, brightly coloured fly is undoubtedly one of the most valuable insect enemies of *D. maroccanus* throughout Turkestan. It is decidedly polyphagous, developing quite freely on eggs of several of the more important xerophilous locusts, such as *Calliptamus turanicus*, *Ramburiella*, different species of *Dociostaurus*, etc. It is widely distributed, being present in practically all infested areas of Turkestan and N.E. Afghanistan.

In the Dalversin Steppe the first adults appeared at the end of May. Mating and oviposition takes place from 7th to 25th June, coinciding with the oviposition period of the main host, *D. maroccanus*. The egg-laying of *Callistoma* occurs actually in the places where the locust swarms oviposit. Most of the eggs are laid in occasional holes and fissures in the earth, as many as 80 or even 100 being deposited simultaneously, while others are placed in the pulverised surface layer of the soil by means of the terminal segments of the female abdomen, which are modified into a special digging apparatus. The potential productivity of a female is 1,600 to 2,000 eggs.

The nematode-like, small (2·5–2·8 mm.) primary larvae hatch after a short incubation (about a week). They hunt energetically for the host's egg-pods, burrowing through the soil in different directions, and on reaching the pod enter its lower part. After two moults, which entirely change the aspect of the larva, it assumes full growth, leaves the pod and constructs in the earth a narrow elliptical hole, where it hibernates. Pupation takes place in May. Duration of pupal stage about three weeks.

An average of 20 per cent. of pods of *D. maroccanus* is annually destroyed by the larvae of *C. desertorum* throughout Turkestan, but the infestation of some areas is much higher, and a practically complete destruction of individual egg-deposits occurs quite commonly.

Callistoma soror, Lw., seems to be identical with *C. desertorum*.

12. Cytherea setosa, Par.

This recently described species (1930) is found to be an important parasite of the egg-pods of *Calliptamus italicus* in cultivated lands of the Zeravshan Valley, and of those of *C. turanicus* in the neighbouring desert localities. An average of 13 per cent. of the egg-pods of both species are destroyed annually by the larvae of this fly, and this infestation reaches in some cases to about 40 per cent., or even more.

The bionomics of *C. setosa* closely resemble those of *Callistoma*. Owing to the disperse habits of the host, oviposition occurs in a great variety of places. The eggs are deposited in lots of 1–5 on the surface of the soil in the shade of taller grasses, or placed in the soil in the same manner as described for *Callistoma*. The larval development occurs mainly during July and August. The 3rd stage (full-grown) larvae hibernate.

13. Anastoechus nitidulus, F., var.

Some individuals were reared from egg-pods of both *Calliptamus italicus* and *C. turanicus* in the valley of Zeravshan. In this country the economic importance of this fly is very slight.

14. Anastoechus baigakumensis, Par.

Some individuals were reared many years ago from egg-pods of *Locusta migratoria*.

15. Hemipenthes (Thyridanthrax) pallidipennis, Par., *in litt.*

Described by Mr. S. G. Paramonov from four specimens reared from " oothecae of *D. maroccanus* " at the Uzbekistan Expt. Station of Plant Protection (now Middle-As. Inst. of Plant Prot.), Tashkent, many years ago.

16. Anthrax oophagus, Par., *in litt.*

This species is also new, and will be described by Mr. Paramonov in one of his forthcoming papers.

The larvae develop parasitically in the egg-pods of *Dociostaurus maroccanus*, *D. kraussi*, *D. crucigerus tartarus*, *Ramburiella turcomana* and *Calliptamus turanicus*, and hyperparasitically on the larvae of *Callistoma* and *Mylabris biguttata*, inhabiting them. The percentage of pods infested never exceeds 6–9.

The seasonal cycle includes a partial second generation. The flies of the first (spring) generation emerge early in June and oviposit at the same time as *Callistoma* and the Moroccan locust, and in the same places. The eggs are placed in the powder-like superficial layer of the soil, or thrown into holes and fissures of the soil. The young primary larvae hatch after an incubation period of 5–9 days and are very much like those of *Callistoma*, but about half the size. They undergo two moults and pass rapidly to maturity. Some of the full-grown larvae remain in the pod without change until the following spring, then pupate, and after a pupal period of 16–34 days the adult flies emerge. Other larvae pupate directly after reaching maturity (in July), and the flies emerge in August and September. The flies of the second, or summer, generation oviposit in the same places as those of the first. The larvae of this second generation are still unknown.

17. Anthrax monachus, Sack.

Larvae in the egg-pods of *Ramburiella turcomana* and hyperparasitic on the pseudo-pupae of *Mylabris scabiosae scabiosae* inhabiting them.

18. Anthrax jazykovi, Par., *in litt.*

This new species seems to be closely allied to *A. zonabriphagus*, Portsh. 1895, and is parasitic on prepupal larvae of *Epicauta erythrocephala* in the Zeravshan Valley. Second stage larvae were found feeding upon them in May; full-grown larvae are not uncommon in the earth during June and July. The larvae pupate

late in July, and the adult flies emerge in August. The eggs are laid in the same manner as those of *A. oophagus* in various mesophytic habitats, a total number of about 800–1,000 being deposited by a single female. It is presumed that hibernation takes place as a first instar larva in the soil.

Family TACHINIDAE.

19. Oophagomyia plotnikovi, Rohd.

In the egg-pods of *Locusta migratoria* and occasionally (in 1929) in those of *Schistocerca gregaria* in damp places. This is a rare parasite and insignificant from a practical point of view.

20. Stomatorhina lunata, F.

Reared by my friend Mr. B. B. Rohdendorf from egg-pods of *Schistocerca gregaria* in Turkmenistan, during the great outbreak of this locust in 1929.

HYMENOPTERA.

Family SCELIONIDAE.

21. Scelio nikolskyi, A. Ogl.

Described by Dr. Ogloblin (Bull., 1927. Ent. Res., xvii, p. 399), from some females reared a long time ago (in 1915) by Mr. V. Nagaibakov from eggs of the Migratory Locust. In Ogloblin's original description the locality data are incorrect, the types being from the Maidan-tal district, Tashkent Province, and not Perovsk, as stated by the author.

FOUR NEW SPECIES OF ICHNEUMONOIDEA.

By D. S. Wilkinson,

Entomologist, Imperial Institute of Entomology.

(Plate XX.)

Glypta leucotretae, sp. n.

♀♂. Dark red; head and antennae (except as follows), pro- and mesosternum to a greater or less extent, hind legs entirely (except as follows), apical third or fourth of the 4th tergite, the succeeding tergites, and the ovipositor sheaths, black; apical joint of the scape, the extreme base and extreme apex of the hind femora, the extreme bases of the hind tarsal joints, and the hind tibial spurs, reddened; the four anterior legs (except as follows), and the palpi, more or less red testaceous; the clypeus, mandibles (except the teeth), scape below (in one ♂ specimen), the coxae and trochanters of the four anterior legs, a large elongate spot occupying the basal half of the dorsal surface of the hind coxae, the pronotum, the propleurae narrowly along their upper margin, and the wing-insertions of the fore-wings (but not the tegulae), white; the ventrites and the ovipositor very pale; stigma and wing-veins uniformly opaque brown.

♀♂. *Head* punctate; the face, which is transverse, with the punctures strong and closely placed; the clypeus virtually smooth, not otherwise differentiated from the face, its apex rounded; facial depressions nearer to eyes than to each other, their distance from the eyes about equal to the malar space; mandibles with teeth of equal length; frons with punctures stronger and more widely spaced than on the face; vertex and occiput with punctures as strong as on the frons, but very definitely increasingly more widely spaced as the back of the head is approached; flagellum with 38 joints, the first joint decidedly longer than the second. *Thorax* with punctation much as on the frons, possibly rather more widely spaced, the mesonotum in addition with certain minute, transverse aciculation; the scutellar sulcus broad but not deep, with some crenulation laterally; mesopleurae with a narrow, smooth, oblique area near the oblique posterior margin, otherwise regularly punctate; propodeon with complete areation, regularly punctate except in the areola and basal area of the ♀ where it is weakly transversely rugose. *Legs*: all tarsi with the basal joint longer than the combined length of the 2nd, 3rd and 4th joints, but shorter than the combined length of 2nd-5th joints, with the 5th joint very definitely longer than the 4th; hind coxae punctate, the punctures well and regularly separated and small. *Abdomen*: 1st tergite with length about 1·2–1·33 times its apical breadth, with two well marked, longitudinal carinae, which extend from base almost to apex and divide the tergite into three longitudinal areas, a median and two lateral, of which the former is smooth in basal two-thirds but with some fairly widely spaced, very strong punctures in the apical third, and the lateral areas strongly, closely, and regularly punctate; the apex of the tergite smooth; 2nd–4th tergites transverse, grossly punctate, the punctures tending to form rugosity, with their oblique furrows strongly marked on the 2nd and 3rd, but more weakly so on the 4th, the apices of the tergites smooth, that of the 4th very slightly coriaceous; succeeding tergites smooth (or very minutely punctate), very slightly coriaceous; ovipositor sheaths longer than the abdomen, shorter than the combined length of the thorax and abdomen.

Length, 8 mm.; one ♂ measures 5 mm.

Southern Rhodesia: Mazoe, 3 ♀♀, 3 ♂♂, 12.v.1930 (*type*), 16.v.1930, 10–14.ii.1931 (*W.K.F.*).

Type deposited in the British Museum.

Host. This species is stated to have been bred from the False Codling Moth, *Argyroploce leucotreta*, Meyr.

Two Nearctic species of *Glypta* are recorded to be parasites on the Codling Moth, but from these two and also from those species of *Glypta* described from the Ethiopian and Indo-Australian regions, of which there are only a few, *G. leucotretae* is easily separable on account of the unicolorous red-brown of the dorsum of its thorax in conjunction with the black of its hind legs, together with the absence of any areolet in its fore-wing (an areolet apparently occurring in certain species). *Glypta flavolineata*, Grav., has been recorded from *Argyroploce variegana* in Poland, but this is abundantly different from the species described above. This in Schmiedeknecht's key (Op. Ichn., p. 1184) runs fairly well to *ruficeps*, a species known to me both from the type in the British Museum and from a female bred at our laboratory at Farnham Royal from an apple leaf-roller; but *ruficeps* is quite distinct from *leucotretae*, if only on the conformation of the face.

Mesobracon psolopterus, sp. n.

♀♂. Red testaceous; flagellum, majority of the scape, frons, vertex, occiput, and feet, black; ovipositor sheaths, large portions of the hind tarsi, nigrescent to black, as is the apex of the 6th tergite of the ♂ together with its succeeding tergites; wing-veins and stigma dark brown to black, the wings evenly and deeply infumated throughout save as follows: ♀, fore-wing at extreme base of anal vein and of anal cell, in about basal two-thirds of the costal veins, and in slightly more than the basal half of the stigma, red or red testaceous, beneath the basal third of the stigma, in an area all round the recurrent vein, and narrowly along the 2nd transverse cubital vein, pale, the hind-wing pale below the medial vein at base, ♂ with colouration as in ♀ save that the costal veins of the fore-wing are darkened only at apex and the stigma is darkened only in the apical fifth.

♀♂. *Head*: face indefinitely roughened and to some extent coriaceous, definitely transverse in the ♀, almost as long as broad in the ♂; facial depressions nearer to the eyes than to each other; frons coriaceous, polished, with some minute punctation laterally; vertex smooth, polished, with an occasional minute puncture; occiput smooth, polished, with regular and widely spaced, minute punctation; ocelli with their distance from the eyes fully twice the distance between the posterior pair; flagellum with 55–60 joints. *Thorax* highly polished and with only sparse, minute punctation; scutellar sulcus weak and weakly crenulate, with a very definite, straight, narrow, smooth, impressed line running immediately anteriorly to it transversely across the mesonotum. *Wings* (Pl. XX, figs. 2 & 3): 1st abscissa of radial vein somewhat longer than one-fourth the length of the 2nd, this just shorter than the 3rd, which latter is virtually straight. *Abdomen*: the six basal tergites with the usual coarse reticulation, and the sutures well marked and crenulate; 1st tergite with the apical breadth two-thirds the median length, which is nearly 2·5 times the basal breadth (40 : 60 : 25); 2nd tergite with the converging discal sulci broad but not well marked, in the ♀ with the apical breadth at least 1·33 times the median length, which is equal to the basal breadth (60 : 45 : 45), in the ♂ with the apical breadth 1·22 times the median length, which is 1·125 times the basal breadth (55 : 45 : 40); succeeding tergites transverse, more strongly so in the ♀; extruded portion of ovipositor sheaths about four-sevenths of the combined lengths of the six basal tergites, that is to say it is longer than the combined length of the three basal tergites, but shorter than that of the four basal tergites.

Length: ♀, 7–8 mm.; ♂, 6–7 mm.

SIERRA LEONE: Njala, 6 ♀♀, 2 ♂♂, 4.xii.1930 (*E. Hargreaves*).

Type deposited in the British Museum.

Host. The series is labelled " *ex* coffee branch borer."

This new species will not run in Brues' key (Proc. Am. Acad. Arts Sci., lxi, 1926, p. 239), but in Fahringer's key (Opusc. Bracon., 2, 1928, p. 119) it would appear to run to *luteus*, Cam. (*Telerda*) ; Cameron's species however is immediately separable on wing-pattern. *M. psolopterus* is a species distinctive in the genus. Its nearest ally, or at least the species that it most closely resembles, is *nigriceps*, Cam. (*Telerda*) ; this, however, apart from certain colour differences, has the 1st tergite tumescent medianly and hardly as long as broad, while in addition the venational differences (Pl. XX, fig. 1) are sufficiently well marked.

Camptothlipsis, Enderlein 1918.

It has been suggested to me, and in no uncertain terms, that the absence of the 2nd transverse cubital vein in this and in other related genera, such as *Beognatha*, is due merely to fusion of this vein with the 1st transverse cubital, and that in consequence the presence of only two cubital cells instead of three cannot in these cases be taken to be of any generic significance. I am unable to accept this without very adequate proof, for if it is once accepted it seems to me that any classification of the BRACONIDAE based in any way on venational characters becomes valueless. Before leaving this question, however, it should I think be recorded that in all the specimens of *Camptothlipsis* that I have seen (and there are in the British Museum collections reasonably good series of further species obviously belonging to this genus) not one shows even the very slightest trace of an obsolete areolet, such as is so common in, for example, *Microdus*, in the form of a minute, hyaline, more or less circular area in the middle of the extreme bottom of the transverse cubital vein.

I am very much indebted to the authorities of the Museum für Naturkunde, Stettin, for facilities rendered me in the matter of Enderlein's types.

Only two species are at the moment included in this genus ; to these I am adding in this paper two more, and the four may be separated as follows :—

1. First tergite of female with median length twice apical (greatest) breadth 2
   First tergite of female with median length never greater than 1·53 times apical breadth 3
2. Scutellar sulcus deep, with but a few crenulations, and carinae defining these (save for median carina) weak and at bottom of sulcus (Eritrea) ... ... *perula*, End.
   Scutellar sulcus not deep, with at least eight crenulations, and all carinae defining these well marked and level with disc of scutellum (Transvaal) ... ... *costalis*, End.
3. Second tergite with breadth at most 1·2 times median length ; mesonotum with length definitely greater than greatest breadth ; propodeon swollen (India) ... ... *furtifica*, sp. n.
   Second tergite strongly transverse with breadth 1·75 times median length ; mesonotum with length hardly greater than greatest breadth ; propodeon normal (Sudan) ... ... *antigastrae*, sp. n.

Camptothlipsis furtifica, sp. n.

♀. Red testaceous ; the flagellum, apex of the hind tibiae, the hind tarsi usually, the stigma and wing-veins, red-brown ; ovipositor sheaths dark brown to black.

♂. Agrees with the above colour description for the ♀ except that in three examples the dorsal portion of the propodeon, the 1st tergite, the metanotum, the scutellar sulcus, and the carinae bordering the posterior half of the mesonotum, are black.

♀♂. *Head* smooth, at most with extremely minute punctation; the facial depressions well marked, rather nearer to the eyes than to each other, considerably further from each other than from the apex of the clypeus; the ocellar area somewhat raised, the posterior ocelli rather nearer to each other than to the eyes; flagellum with 26–28 joints. *Thorax* smooth save for minute punctation; mesonotum with length definitely greater than its greatest breadth; the notauli fairly well marked, crenulate but rather indefinitely so, straight (more or less), converging, joining with each other at a point about half way between the scutellar sulcus and the middle of the mesonotum; scutellar sulcus crenulate, the carinae defining the crenulations well marked and level with the disc of the scutellum; propodeon with distinctly coarser sculpture than on the mesonotum, particularly towards the base, otherwise without sculpture or carination, but decidedly swollen. *Legs*: the longer hind tibial spur hardly more than two-fifths, and the shorter spur one-third, the length of the basal joint of the hind tarsus, this latter about equal to the combined length of the remaining joints of the hind tarsus together with the foot. *Wings*: 1st abscissa of the radial vein not punctiform. *Abdomen* not sculptured save that the 1st tergite is weakly coriaceous, and that the 2nd tergite is extremely weakly coriaceous with the semicircular impression obsolete to wanting; 1st tergite decidedly convex, with the sides straight and slightly diverging in about the basal three-fourths, slightly rounded and more or less parallel to slightly converging apically, the median length in the neighbourhood of about 1·3–1·4 times the greatest breadth (*i.e.*, slightly before apex); 2nd tergite hardly broader than long, its breadth about 1·17 times its median length; 3rd tergite distinctly shorter than the 2nd; extruded portion of the ovipositor sheaths about as long as the combined length of the head, thorax, and abdomen.

Length: ♀, 4·75 mm.; ♂, 4·0 mm.

India: Chichawatni Plantation, Punjab, 1 ♀, 7.v.1928 (*type*), 2 ♂♂, 11 & 12.v.1928 (*R. N. Mathur*), 5 ♀♀, 19.vi.1929 (*B. M. Bhatia*), 1 ♀, 3 ♂♂, 15 & 30.vi.1928, 8.viii–2.ix.1928, 1 ♀, 2 ♂♂, 15–30.iv.1928 (*R. N. Mathur*).

Type deposited in the British Museum.

Host. The first three specimens mentioned above were bred from larvae of the Tineid (Gelechiid) moth, *Dichomeris evidantis*, Meyr., defoliating *Dalbergia sissoo.*

Camptothlipsis antigastrae, sp. n.

♀♂. Red testaceous; antennae brown; ovipositor sheaths dark brown to black; feet darkened; costal veins and stigma red testaceous; wing-veins otherwise rather pale red-brown.

♀♂. *Head* smooth, at most with extremely minute punctation; the facial depressions well marked, about equidistant from each other and the eyes or rather nearer to the eyes, considerably further from each other than from the apex of the clypeus; the ocellar area more or less raised, the posterior ocelli rather nearer to each other than to the eyes; flagellum with 26 or 27 joints. *Thorax* smooth, with only indefinite punctation; mesonotum with its length hardly greater than its greatest breadth; the notauli fairly well marked, at the most weakly and indefinitely crenulate anteriorly, strongly converging to a point at about the middle of the mesonotum, but hardly joining, there angled, and thence proceeding parallel with each other down the middle of the mesonotum and very quickly becoming lost; scutellar sulcus crenulate, the carinae definining the crenulations well marked and level with the disc of the scutellum; propodeon with some distinctly coarser

punctation and sculpture than on the mesonotum, particularly towards the base, and also to some extent minutely coriaceous, otherwise without sculpture or carination, normal, not swollen. *Legs*: the longer hind tibial spur half, and the shorter spur about three-eights, the length of the basal joint of the hind tarsus, this latter about equal to the combined length of the remaining joints of the hind tarsus together with the foot. *Wings*: 1st abscissa of the radial vein not punctiform. *Abdomen* not sculptured save that the 1st tergite is weakly coriaceous and the semicircular impression on the 2nd tergite is well marked; 1st tergite with the sides straight and diverging, the median length in the neighbourhood of at most 1·4 times the apical breadth; 2nd tergite strongly transverse, its breadth 1·75 times the median length; 3rd tergite equal to or rather longer than the 2nd; extruded portion of the ovipositor sheaths about as long as the combined length of the head, thorax, and 1st tergite.

Length, 4·0–4·5 mm.

ANGLO-EGYPTIAN SUDAN: Khartoum, 1 ♀ (*type*), 1 ♂, 1.i.1929 (*H. W. Bedford*); Shambat, 4 ♀♀, 2 ♂♂, 8.xii.1928, 28.xii.1928, 5.i.1929 (*H. W. Bedford*).

Type deposited in the British Museum.

Host. This series is labelled as a parasite of the virtually cosmopolitan Pyralid moth, *Antigastra catalaunalis*, Dup.

Apanteles taragamae, Viereck 1912.

We have lately received of this species the following material:—

CEYLON: Colombo, 23 ♀♀, 8 ♂♂, 21.i.1931 (*Dr. J. C. Hutson*); Jaffna, 17 ♀♀, 6 ♂♂, 23.xi.1930 (*Dr. J. C. Hutson*).

Host. Of this material, that from Colombo is labelled as having been bred from the larva of the Pyralid moth, *Margaronia* (*Diaphania*) *indica*, Saund., on melon, and the remainder from the same host, but on *Trichosanthes anguina*, the snake-gourd.

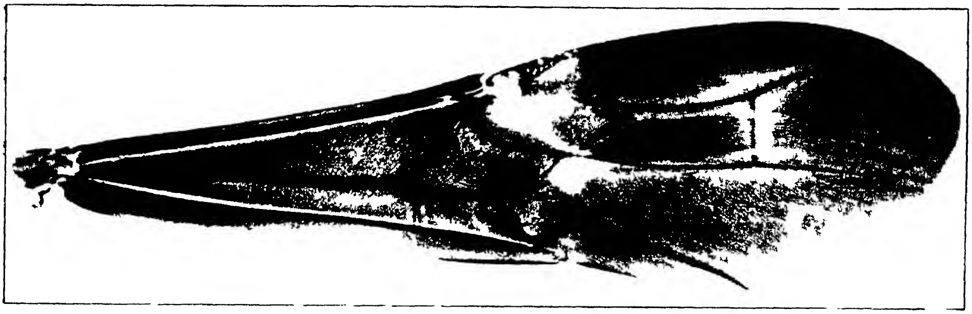

Fig 1 *M nigriceps* Cam

Fig 2 *M psolopterus* sp

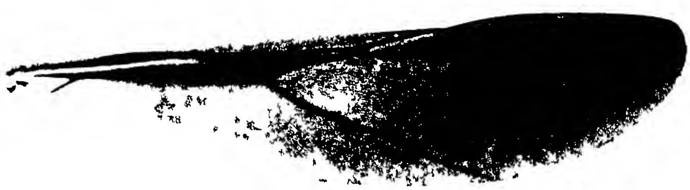

Fig 3 *M psolopterus* sp n

Wings of Mesobracon spp

ON THE OCCURRENCE IN THE SUDAN OF *LOCUSTA MIGRATORIOIDES*, RCH. & FRM., AND ITS ASSOCIATED PHASES.

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and
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One of the most remarkable features of the locust season during the summer and autumn of 1930 in the Sudan was the unexpected and widespread occurrence of *Locusta migratorioides*, R. & F. Swarms, which laid eggs over a large extent of the country, entered from the west and south-west during July and August. There is no evidence of any of these swarms having been produced within the Sudan, and the place of origin of all the early swarms was without doubt situated outside its boundaries. There is evidence that breeding continued later in the southern portions of the country, particularly in the upper reaches of the White Nile (N. Lat. 5°), and movements of swarms were reported during the winter, but no reliable observations were made on the nature or extent of these activities. Only one brood was produced in the northern and central Sudan (probably north of N. Lat. 11°), and by October all locusts bred in these parts had either migrated away in swarms or had scattered. Migration took place in the case of the gregarious phase produced by large bands of hoppers. Where, however, bands of hoppers had been broken up by poisoning, or in cases where the bands were very small, the adults did not migrate. The absence of further breeding in the northern Sudan must be connected with the absence of winter rains and suitable vegetation. No previous records exist of the occurrence of this species in the Sudan, and native opinion, which seems clearly to distinguish this locust from the better known *Schistocerca gregaria* (Desert Locust), places the last appearance of swarms similar to those here referred to about forty years ago. In this connection it is interesting to note that there occurred in the French Sudan[2] between 1899 and 1902 a period during which *L. migratorioides* was very common and injurious.

Observations over a wide area during the period of its occurrence were not possible, and the information given here was obtained in only a few localities in the northern Sudan. It has seemed important, however, to record both the appearance of this locust, and at the same time the scanty information available on the various associated phases occurring in the country.

The nomenclature of locust phases proposed by Uvarov & Zolotarevsky,[5] which has greatly assisted the study of the subject, is employed here.

Very little is known as yet regarding the occurrence and interrelationships of the phases of *Locusta* in the Sudan. The phase *solitaria* (=*L. danica*, L.) is a common insect found singly almost throughout the whole country. Individuals which must be classed as the phase *gregaria* (formerly determined as *L. migratoria*, L.) have been repeatedly produced experimentally by crowding the "*danica*" larvae, and in localities where the larval bands were small, they were the normal type of adult resulting from eggs laid by the immigrant *migratorioides* swarms. Moreover, insects which both in the larval and adult condition seem to occupy an intermediate position between the *solitaria* and *gregaria* phases have been noticed in certain districts. These undoubtedly represent the phase *congregans*. The phase *dissocians*, though at present it has been very little studied, has been recognised in cases where bands of hoppers have been broken up by poison and in cages when a heavy mortality or other large reduction in numbers has taken place.

The relationship of *L. migratorioides* to these phases has not yet been sufficiently studied in the Sudan. It has been observed to enter the country from without and has laid eggs in the country. The resulting adults in most localities resembled in all essential respects their parents, but in a few localities they were nearer to *L. migratoria*. It would appear most probable that *L. migratorioides* must be regarded as the extreme swarming form towards which the phases *congregans* and *gregaria* are steps. Only a more extended study over a wide area, and particularly in the place of origin of these swarms, can throw light on this subject. Recent work by Zolotarevsky[6] in Madagascar has shown that the migratory locust of that island is a subspecies distinct from that of the African mainland and possessing its own phase-circle. It may be stated here that by no form of breeding experiment has it been found possible to produce large numbers of *L. migratorioides* similar to those which arrived in swarms, though locusts somewhat closely approximating to them have been obtained by crowding the larvae, and specimens received from Mongalla Province in the southern Sudan are almost identical with them.

The following diagram, suggested by Zolotarevsky's paper may make clear our present knowledge on the subject of the phases of *Locusta migratoria* in the Sudan :—

Phase *solitaria*
Larvae : Green or various colours
Adults : Green or Brown

Phase *dissocians*
(very varied in colour
and structure)

Phase : *congregans*
Larvae : Brown—few green.
Adults : Brown—few green.

Phase *gregaria*
Larvae : Black and orange
Adults = *L. migratoria* (in cages and field).
L. migratorioides (in field).

At this point may be given in tabular form the most important differences between the phases in the Sudan. For the purposes of this summary *L. migratorioides* is regarded as the extreme form of the phase *gregaria*.

Phase solitaria.

This is the equivalent of the species previously known as *Locusta danica*, L. It is of wide distribution in the northern Sudan, particularly in the vicinity of cultivation. Records of its occurrence extend southwards to Lat. 12° N., but lack of observation probably accounts for its apparent absence from districts still further south. In the north its distribution is chiefly determined by that of the grasses which provide its food. Both in the hills on the east and in the valley of the Nile, as well as in almost any khor or depression where grasses can maintain some verdure throughout the year, scattered individuals may be found at any time. The period of diapause is passed as an adult, and breeding is confined to the season of rain.

Adults of this phase possess the same variability of colour which has been noted in other countries in which it occurs. The usual colour is green, but various shades of brown and even grey have been noticed. It is not known, however, how far these may be associated with a *transiens* phase. Other points regarding the external appearance of this phase are these: the elytra are light brown with dark patches, which vary enormously in the depth of their shades, being sometimes almost entirely

TABLE I.

Differences in Phases of Locusta migratorioides.

Phase *solitaria* = *L. danica*, L.	Phase *transiens* (as observed on Red Sea in 1926)	Phase *gregaria* = *L. migratoria*, L.	Phase *gregaria* = *L. migratorioides* Individuals from swarms.
Colour : Usually green, sometimes brown or grey	Brown, seldom green	Greyish brown	Orange-brown to yellow.
Pronotum : Front margin angular Hind angle acute Keel : High and convex Dorsal dark areas : Absent	Less angular More rounded Convex Absent or obsolescent	Rounded Rounded Low and straight in profile Usually strongly marked	Rounded, often nearly straight. Broadly rounded. Usually very low and concave in profile. In young adults strongly marked, in sexually mature adults absent or obsolescent.
Elytra : Relatively shorter	As in phase *solitaria*	Relatively slightly longer ; dark area at apex	Relatively distinctly shorter ; dark area at apex.
Hind femora : Relatively longer	As in phase *solitaria*	Relatively slightly shorter	Relatively distinctly shorter.
Sexual dimorphism : ♂ 23 per cent. smaller than ♀	♂ 19 per cent. smaller than ♀	♂ 12 per cent. smaller than ♀	♂ 12 per cent. smaller than ♀.
Larvae : Frequently green, often brown or grey ; occur singly	Seldom green, but brown or black and orange ; in small bands	Black and orange	Black and orange ; in bands of various dimensions.
Non-migrant	Non-migrant	Probably non-migrant	Migrant.

TABLE II.

Showing Dimensions of Phase solitaria.

Locality	Date	Number of specimens	Total length	Length of elytra	Length of H.F.	Length of pronotum	Breadth of pronotum	Breadth of head	E./H.F.	B.P./B.H.
Medani	vii.1925	8 ♂	49·06	39·24	20·74	7·74	5·24	5·81	1·89	0·90
		11 ♀	64·94	52·40	27·26	10·81	7·36	7·95	1·92	0·92
Mettemeh	xii.1927	1 ♀	64·00	51·00	28·00	10·50	7·00	7·50	1·82	0·93
Medani	v.1925	3 ♂	49·25	39·25	22·16	8·16	5·50	6·00	1·77	0·91
		4 ♀	67·00	54·50	29·00	11·25	7·75	8·00	1·87	0·96
El Temerab	i.1928	2 ♂	50·25	40·50	21·75	8·50	5·50	5·75	1·86	0·95
		3 ♀	68·16	53·33	29·50	11·16	7·33	8·16	1·80	0·80
Shendi	ix.1926	2 ♂	53·25	43·00	23·00	8·25	5·75	6·00	1·87	0·96
		2 ♀	68·00	55·00	28·75	10·25	7·75	8·50	1·91	0·91
Medani	ix.1927	1 ♂	54·00	43·50	24·00	8·50	6·00	6·00	1·81	1·00
		1 ♀	68·50	55·00	28·50	11·00	7·50	8·00	1·93	0·93
Khartoum	viii.1924	3 ♂	49·66	39·83	21·16	7·83	5·50	5·66	1·88	0·97
		2 ♀	67·50	55·25	27·75	10·50	7·50	7·75	1·99	0·96
Kassala	v.1926	2 ♀	68·75	56·00	27·25	10·50	7·75	8·25	2·05	0·93
Tokar	iii.1926	2 ♂	53·50	42·75	23·00	8·75	6·00	6·00	1·85	1·00
		2 ♀	67·75	56·50	29·50	11·50	7·75	8·00	1·91	0·96
Khartoum	vii.1926	4 ♂	50·22	40·50	21·75	8·12	5·50	5·87	1·86	0·92
Berber	ix.1925	3 ♀	64·83	51·66	28·50	11·16	7·50	8·00	1·81	0·93
Medani	viii.1925	1 ♀	67·00	53·00	29·50	11·00	8·00	9·00	1·79	0·88
Gebelein	vii.1925	2 ♀	67·00	53·75	30·00	11·50	8·00	8·00	1·75	1·00
Khartoum	viii.1930	2 ♂	50·75	40·25	21·75	8·00	5·50	6·25	1·85	0·88
Reared specimens ...		2 ♀	65·00	51·75	28·25	10·50	7·50	8·00	1·83	0·93

Elytra : Maximum ... ... ♂ 43 mm.
♀ 58 mm.

Minimum ... ... ♂ 38·5 mm.
♀ 48 mm.

obsolete. The infumated area, present almost always at the apex of the elytra in the swarming phases, is invariably absent in this phase. Vestiges of the long black areas on the upper surface of the pronotum, which are always present in adults of the phase *gregaria*, may sometimes be seen more or less distinctly in those of the phase *solitaria*, but this again may indicate the phase *transiens*, and may depend for its intensity on the position of any individual in the phase-circle.

It is in the details of structure that the most reliable diagnostic characters may be found, and these correspond closely to those described by Uvarov[4] for the European examples. The unreliability of the structural characters of the head, as indicated by Uvarov, has been confirmed in specimens from the Sudan, and reliance for the separation of individuals belonging to different phases has been placed in the structure of the pronotum, and in the ratios existing between measurements of elytra, hind femora, pronotum and head. In these respects the solitary phase shows a high convex median keel, the fore margin angular and the hind angle acute, whilst the elytra are relatively shorter and the hind femora relatively longer than in the gregarious phase. Moreover, the head is relatively narrower.

The obtaining of long series of the solitary phase from one locality and at one time is a matter of difficulty. The measurement of large numbers of specimens has up to the present therefore not been possible. The dimensions of some sixty specimens from the Government Collection taken in the field are given in Table II, but it must be acknowledged that much larger numbers should be examined and from many more localities.

A strong sexual dimorphism is seen to exist, since males are smaller in total length than females by 23 per cent. of the length of the latter. As will be seen later, this is much greater than in the other phases.

The life-history of the solitary phase in the Sudan has been very little studied. From breeding experiments made in the summer of 1926, in which hoppers from solitary parents were reared singly in cages, it was found that the incubation period lasted 7 to 12 days, with an average of 8·5 days. The total duration of the larval stages was 27 to 30 days. In 1930 these were repeated with typical *solitaria* adults taken in the field. The incubation period (*i.e.*, the interval between laying and hatching) was an average of 14·7 days, with a maximum of 15 days and a minimum of 14 days.

In 1926 two subsequent generations were reared in similar manner. Copulation took place in 8–12 days after the 5th moult, and eggs were laid 25 days after moulting. It is almost certain that in the field in that year this did not take place and that probably only one, with possibly a partial second, generation was produced. The governing factor is almost certainly rainfall and the continuance of grasses in a green state. The chief grasses which serve as food for the larvae are of the genera *Cymbopogon*, *Panicum* and *Pennisetum*, but further observation will probably reveal many others.

The larvae during the first stage are brown in colour. This colour in various degrees of intensity may persist up to the ultimate stage, but the vast majority of hoppers become green before the last moult and as a rule in the second or third instar, the colour change actually taking place at the moult. There is little change in the appearance of the larva once the green colour is assumed.

The antennae are whitish, apical portion dark. Head green, with exception of trophi, which are of variable colour. Mandibles partly red and blue. Clypeus and palpi straw-coloured. A strong whitish line edged with black extends from behind the eye to the pronotum. The latter, which is strongly compressed laterally, is

entirely green, except for a whitish mark on the anterior margin on each side, and a central area of black dots on each lateral lobe. Keel strongly convex and with a clear median white line. Metanotal segments with numerous small black spots on the hind margin. The rudimentary wing has a strong and conspicuous black tubercle at its base. First and second pairs of legs straw-coloured; hind femora green on both surfaces, hind tibiae as fore legs. There is no essential difference between larvae reared in cages and those found in the field.

During the season of rains these larvae may be found chiefly among tufted grasses singly, hardly ever being associated even in pairs. They are difficult to see and are rarely found except by careful search. Repeated observation proves however that under such favourable conditions as are provided by heavy and long-continued rainfall and consequent abundant food, these solitary hoppers may begin to aggregate into small bands, and then constitute the phase *congregans*.

Phase congregans.

Very little is known regarding the transition from the solitary to the gregarious phase in the Sudan, and in fact it is doubtful whether the complete transition ever takes place in the field, at any rate in the northern portions of the country, where any evidence of the origin of migratory swarms is wanting.

What must, however, be designated a *congregans* or incipient swarming phase was observed in April 1926 on the Red Sea coast near Port Sudan. Rains during the winter had been abnormally heavy, amounting to 404 mm. for the months November to February, as compared with an average of 75 mm. for the same months during the ten previous years. The raintall in this region varies considerably both in amount and distribution. At the time referred to, a very luxurious short grass association had sprung up, extending almost continuously over more than 200 miles of the coastal plain. The solitary phase, which occurs commonly in this region, finding suitable conditions for breeding, passed through several generations between November and March, and in the latter month small bands of hoppers, which varied much in size but never exceeded a few thousand individuals, were met with at short intervals wherever grasses occurred. That these bands were due to the breeding of solitary individuals is certain, since no migrant swarms had passed, nor, as has been indicated, were such known until 1930. It is of much interest to note that on this occasion similar bands of *Schistocerca gregaria* phase *congregans* had also been produced from the solitary or *flaviventris* phase of this species. The latter progressed, however, more rapidly and were on the point of attaining the phase *gregaria*, whereas the former never showed so complete an approach to this condition.

The vegetation of this coastal region may roughly be divided into three zones, namely, a xerophytic or halophytic association next the sea; an intermediate one composed of short grasses interspersed with *Sueda* and a few dwarf acacias; and the associations on the ground nearer the hills, which supports larger trees but which is without a close ground vegetation. It is in the second of these zones that breeding takes place. The main grasses fed on by the larvae were species of *Panicum* and *Aristida*.

The behaviour of these hoppers was not closely studied, but one fact concerning their feeding habits deserves mention. They exhibited marked geophilous tendencies, preferring grasses of low habit. Moreover, plants other than grasses were not attacked, and when ground on which cotton grew was invaded, the hoppers never ascended these plants but remained and fed on the grass beneath, nor could they be persuaded in cages to feed on cotton, even under the urge of hunger, except very sparingly. The larvae of *Schistocerca gregaria*, which occurred in the same locality, fed on a wider range of plants and were not at all geophilous.

In colour the larvae of phase *congregans* probably vary considerably, but the larger number of those observed in 1926 were brown. Similar bands observed by the junior author in 1930 were of the swarming colour, and a wide range in colour probably exists, demonstrating the extreme plasticity of the larva in this respect. This is borne out by observations of varying degrees of crowding in cages, where as a rule colour deepens and approximates to the true swarming condition in proportion to the number of hoppers associated together.

The adults are light brown in colour, and green forms are in the minority. In 1926 they were in the proportion of 77 per cent. to 23 per cent. The black pronotal streaks are absent or obsolescent, and the pink tinge is absent from the hind tibiae. In structure there is only a slight variation from that of the solitary phase. The pronotal keel is high and convex and the front margin produced. In many specimens the hind angle is more rounded, as in the phase *gregaria*. In size, individuals of this phase are smaller than those of the solitary, and sexual dimorphism is present, since the average length of the male is less than that of the female by 19 per cent. of the length of the latter. The accompanying Table III gives measurements of this phase in 1926 and again in 1930 in the same region. The amount of material examined is admittedly small, but sufficient evidence is present to show the affinity of adults bred from these small bands to the solitary phase. Moreover, the presence in the same locality of almost identical forms at dates four years apart would point to the influence of climatic factors both in bringing about an incipient swarming and in inhibiting its further progress to the true migrant state. It is believed therefore that the phase *congregans* in the Sudan, though it is exceedingly unstable, possesses a distinct identity. It must be pointed out, however, that, in the Sudan, as elsewhere, the terms *congregans* and *dissocians* cannot be applied to any single individual locust without a knowledge of the circumstances under which it was bred and the nature of the next generation to which it gives rise. In other words these terms must be regarded at present rather as the names of positions in the phase-circle than as those of any particular type of locust.

Summarising our knowledge of this phase it may be said that in localities having a desert type of climate but subject to periods of rainfall, the *solitaria* passes to the *congregans* phase, and this phase tends again to pass to *gregaria* in so far as climatic conditions approximate to the optimum for that phase. That these latter conditions are absent from the northern Sudan is certain, and further study will reveal how far they are present in the regions nearer the equator.

Phase gregaria.

Notice was first drawn to this phase in the Sudan when two specimens submitted in 1925 to the Imperial Institute of Entomology were determined as *Locusta migratoria*, L. These had been obtained in August 1924, when by crowding the larvae of *Locusta danica* in cages, individuals differing greatly both in appearance and structure from the parents were bred. In 1926 these experiments were repeated, and solitary parents were induced to breed in captivity, the larvae being reared from the 1st instar to the number of thirty in a cage. No records of larval changes were preserved, but the adults corresponded closely to those obtained two years before. Again in 1930 similar broods were reared, as will be mentioned later. The adults were of the same type. The extent to which they tended away from the solitary phase was found to be roughly in proportion to the degree of crowding resorted to. A continuous series could be arranged showing an unbroken gradation of specimens joining a typical *L. migratoria* to a similarly typical *L. danica*. The phase *gregaria* therefore is extremely unstable. Nevertheless it has an undoubted entity, and it is quite possible to obtain

by crowding a long series which shows little variation. What may be called a generalised type of the adult of this phase may be described :—

Colour greyish brown, abdomen darker. Head greyish. Mandibles and frontal carinae bluish. Genae with rectangular dark patches continued above to form a dark coloration on the epicranium and vertex. Eyes very dark. A white line edged with black running behind the eye to meet a short white mark on the anterior margin of pronotum. A low central keel on the fovea of the vertex and continuing as a faint white line on the epicranium. Pronotum greyish brown, frequently very faintly reddish, with a long black mark on each side of the keel, which is irregular and broken in the pro- and mesozonal areas, but more rectangular in the metazone. Keel low and usually of even height. Front margin sub-acute. Hind angle sub-acute to rounded. Meso- and metanotal segments greyish with black spots and margins. Abdomen dark bluish grey dorsally. Wing hyaline, with an infumated area at the apex measuring about 8×5 mm. A similar overlapping area on the elytron gives a very characteristic dark colour, always absent in the solitary phase. Thoracic sternites covered with a dense grey pubescence. Hind femora almost entirely black on the inner surface, and next the coxae, and with 11 black-tipped spines on the inner surface and 12 on the outer. Total length of ♂ 53–56 mm. and of ♀ 60–64 mm. ; elytra relatively longer than in phase *solitaria*, hind femora relatively shorter. Sexes less dimorphic in regard to size, since the average total length of the male is less than that of the female by 12 per cent. of the length of the latter.

Individuals have been kept under observation for two months and a tendency to yellowing of the head pronotum and legs has been noticed.

As regards the larvae, since these correspond fairly closely with those described from other countries, particularly by Pratt[3], they need not be described here. There is moreover no essential difference between them and those of *L. migratorioides*, which are dealt with later.

Individuals corresponding to the foregoing description are normally obtained by crowding the larvae of the solitary phase in cages. In the field they have been noticed to occur in certain cases where small bands of hoppers from eggs laid by immigrant swarms of *L. migratorioides* have reached maturity, thus establishing the existence of a close connection between these two forms, which will be discussed later.

Phase dissocians.

Very little study has been devoted to this phase in the Sudan. It is believed that it has been observed on the following occasions : (1) In cages when a mortality among crowded hoppers has reduced the numbers to a considerable extent ; (2) when hoppers of the phase *gregaria* have been reared in spacious cages ; (3) in the field, when bands have been broken up by poisoning operations. In the first two cases the hoppers have been found to vary immensely in colour, and the adults have approximated more or less closely to the phase *solitaria*. The changes in the hoppers, which follow the carrying out of control measures in the field, have not been observed, as has been done in the case of *Schistocerca gregaria*,[1] but an interesting observation on the adults may be mentioned. In September 1930, in the Fung Province, Sudan, certain large bands of hoppers from eggs laid by *L. migratorioides* were broken up by the poison bait. The survivors did not congregate, but reached maturity as solitary individuals. The locality was visited three months later. By this time the vegetation had withered, and weeds together with some secondary growth of the dura (*Sorghum vulgare*), which had supplied the hoppers with food, only remained. Nevertheless, large numbers of solitary locusts were met with on and near the places where control operations had taken place, and it is reasonable to suppose that they were the survivors from the larval bands. With considerable difficulty, owing to their

TABLE III.

Showing Measurements of Phase congregans *as observed on the Red Sea Coast.*

Locality	Date	Number of specimens	Total length	Length of elytra	Length of H.F.	Length of pronotum	Breadth of pronotum	Breadth of head	$\frac{\text{E.}}{\text{H.F.}}$	$\frac{\text{B.P.}}{\text{B.H.}}$
Khor Arbaat	iii.iv.1926	57 ♂	51·75	41·15	21·80	7·97	5·72	6·17	1·88	0·92
		29 ♀	62·05	49·90	26·20	10·10	6·70	7·55	1·90	0·88
Khor Baraka ...	ii.xii.1930	7 ♂	51·28	41·21	22·64	8·21	5·50	6·00	1·82	0·91
		8 ♀	66·81	53·56	28·87	10·68	7·17	8·06	1·85	0·88

TABLE IV.

Showing Measurements of Phase gregaria *obtained by crowding larvae of Phase* solitaria.

Locality	Date	Number of specimens	Total length	Length of elytra	Length of H.F.	Length of pronotum	Breadth of pronotum	Breadth of head	$\frac{\text{E.}}{\text{H.F.}}$
Khartoum	viii.1924	30 ♂	53·16	42·66	23·33	7·83	5·66	6·33	1·82
,,	,,	25 ♀	64·16	52·33	27·33	9·50	6·50	7·83	1·91
,,	,,	50 ♂	54·20	43·70	22·90	8·00	5·80	6·70	1·86
,,	,,	50 ♀	60·60	48·70	25·20	8·70	6·70	7·70	1·93
,,	,,	50 ♂	56·60	45·10	23·70	8·60	5·80	7·00	1·90
,,	,,	50 ♀	62·00	49·90	25·50	9·60	6·70	7·90	1·95
,,	,,	50 ♂	55·00	43·60	22·70	8·30	5·80	6·80	1·92
,,	,,	50 ♀	61·00	49·30	25·40	9·00	6·60	7·30	1·93
,,	,,	50 ♂	53·80	43·50	22·80	8·20	6·40	6·60	1·90
,,	,,	50 ♀	60·60	48·70	25·50	8·80	6·40	7·80	1·90

TABLE V.

Showing Measurements of L. migratorioides.

Locality	Date	Number of specimens	Total length	Length of elytra	Length of H F.	Length of pronotum	Breadth of pronotum	Breadth of head	E. / H. F.
Medani	26.vii.1930	100 ♂ 100 ♀	60·15 64·60	48·60 52·40	22·55 24·25	8·05 8·70	5·95 6·70	7·45 8·30	2·15 2·16
Medani	27.vii.1930	2 ♂	59·50	47·50	22·00	8·00	6·00	7·25	2·15
Medani	29.vii.1930	4 ♂ 1 ♀	60·50 65·00	48·17 52·00	21·75 23·50	7·87 8·50	5·62 6·50	7·37 8·50	2·26 2·21
Hag Abdulla	4.viii 1930	3 ♂	61·66	49·50	22·83	8·00	6·00	7·66	2·16
Medani	9.viii.1930	3 ♂ 3 ♀	62·00 64·16	50·00 51·00	22·05 23·83	8·16 8·33	5·83 6·83	7·50 8·16	2·22 2·14
Medani	11.viii.1930	97 ♂ 82 ♀	61·05 66·33	49·00 53·80	22·65 24·54	8·10 8·75	6·05 6·75	7·50 8·37	2·16 2·19
Medani	20 viii.1930	2 ♀	69·00	55·25	25·25	9·25	7·00	8·50	2·18
Melut	xi.1930	19 ♂ 25 ♀	61·71 65·30	50·60 52·80	23·05 23·64	8·00 8·34	6·05 6·40	7·68 8·24	2·19 2·23
Northern Kordofan* ...	ix.1930	9 ♂ 15 ♀	60·62 65·10	49·00 53·10	22·62 24·24	8·00 8·70	5·87 6·24	7·62 8·10	2·16 2·18

* These specimens were from swarms in the field which were the progeny of the previous immigrant swarms.

wariness and great activity, a fairly long series was obtained. The specimens varied very greatly, forming a close chain connecting typical *solitaria* specimens with those equally typically of the phase *gregaria* (=*L. migratoria*). None resembling *L. migratorioides*, however, could be found.

It is supposed that were rain to fall and conditions become favourable for breeding, these could either revert to the gregarious phase through the renewed massing of the larvae into bands, or become typically solitary by the passage of the larvae through one or more generations as single and isolated individuals. This phase must be regarded as unstable, characterised by an extreme diversity of external form and capable at any time of going forward to the solitary condition or again becoming gregarious, according entirely to the climatic and other conditions. It must be remarked, however, that in the Sudan at any rate these statements are somewhat conjectural and still await experimental confirmation.

Locusta migratorioides.

This locust was met with for the first time in the Sudan in 1930 in the shape of swarms entering the country from the west. The colour of individuals composing these swarms is fairly constant though the sexes differ considerably in appearance.

The males have the head (front and genae) yellow, antennae brown, eyes dark brown. Vertex and disk of pronotum dull reddish brown. Fore-limbs red brown. Hind legs, especially the tibiae, yellow. Underside of abdomen yellow. Elytra and wings, when folded, with a faint fuscous area at the apex. The wings hyaline, sometimes with a very faint yellow suffusion at the anal area.

The females, which are usually somewhat larger than the males, differ from the latter in the diminution of the yellow colour on the head, pronotum and legs. Of the parts of the hind legs, the tibiae are generally alone bright yellow.

Both sexes carry a thick pubescence on the thoracic sternites, a character which is absent from individuals of the solitary phase. In the case of some swarms there was present a green tinge on the head and pronotum.

Only in the case of two swarms was a sufficiently large amount of material obtained for measurements, which are given in Table V. It is seen that the ratio $\frac{\text{E.}}{\text{H.F.}}$ is distinctly higher than in other phases. Also sexual dimorphism is less pronounced, since males are shorter in total length than females by 12 per cent. of the length of the latter, as compared with 23 per cent. in phase *solitaria*.

Here again, as regards structure, the characters of the pronotum show the most reliable points of difference. The front margin is not pointed, and in many cases it is merely sinuous or almost straight. The keel is very low, never convex, seldom straight and usually concave. The hind margin is much more rounded and with no appearance of angularity.

As regards measurements, greater variation was found to exist between individuals of the same swarm than has been found by previous workers. This may be accounted for by the mingling of individuals from various swarms which undoubtedly took place.

Habits of Adults.

Certain points observed in the habits of the migrant adults deserve mention here. Swarms arrived generally from the west in the Khartoum and Wad Medani districts at various times in the day. Those arriving about sunset rested for the night, and no

indication was obtainable of their passage by night. They rested on low vegetation and crops as well as on trees and departed in the morning at about 8 a.m. Atmospheric temperature observations taken on three occasions at the time of their departure showed respectively 26° C., 28° C., and 28° C. When it was desired to move a swarm somewhat earlier, this could usually be done, a number of men passing twice over a field being sufficient to clear it, the locusts taking flight at a steep angle and continuing flight down wind.

The rate of travel of swarms was roughly estimated by pacing individuals over short measured distances on horse-back. The average rate calculated for a number of observations was 13·9 miles an hour with a light following wind for swarms travelling near the ground. This rate would probably be increased in the case of swarms moving before a stronger air current.

The altitude of swarms observed was lower than that of similar swarms of *Schistocerca gregaria*. This at first was believed to be due to their passing over a cultivated area ; but this was not so, since similar low altitudes were observed in uncultivated districts.

Feeding by resting swarms usually took place to a greater or less extent. Those which had rested for the night sometimes fed both before sunset and again before departure, if suitable food was available. Frequently also swarms or parts of swarms would alight, feed for a short time, perhaps half an hour, and again take to the wing, leaving hardly any behind.

In one interesting case part of a swarm remained after the major portion had moved on. On the following day these locusts were seen to join another swarm which passed the same point at a very low elevation. In this way undoubtedly members of various swarms become intermingled.

Egg-laying.

Observations on *Schistocerca gregaria* have shown that on the maturation of the eggs, these are laid during a comparatively short period, after which the female dies. In the case of *L. migratorioides* this period is usually much extended, and females are able to lay many egg-pods at short intervals. Swarms in transit have been noticed to alight and rest some time during which eggs were laid, and on several occasions when swarms were flying low over irrigated country individuals were noted leaving the swarms and remaining on the ground and low vegetation. Among these were many females containing eggs fully matured. Again, after the passage of swarms, females gravid with matured eggs have been found remaining behind.

Numerous observations of females kept in cages provide confirmatory evidence. Those taken from swarms continued to lay over varying periods. The longest was 18 days, during which six egg-pods were laid. The female was kept solitary. All the egg-pods proved fertile. Eggs had also been laid in this case prior to capture.

Similar data are provided by females reared in cages. One female moulted to adult on 25.ix.30 and five days later was *in copula*. Eggs were laid twelve days after the last moult. Altogether eleven egg-pods were laid during thirty days, all of which proved fertile. A very much longer period of egg-laying has been noted in the case of the solitary phase reared in cages. As, however, the conditions were unusually favourable, it is improbable that such prolonged periods ever occur in the field.

It may be remarked here that up to the end of March 1931 four successive generations were reared in cages from eggs laid by immigrant swarms in September 1930. This would seem to indicate that, given food, these locusts will continue breeding even in the absence of a decided humidity.

As regards the type of soil in which eggs are laid, *L. migratorioides* does not show the strong preferences of *S. gregaria*. The latter seeks sandy places which have been

moistened by rain. The eggs of the former are laid in both light and heavy soils. Where, in cages, both sand and a heavy clay were provided, females would lay in either, though a slight preference was displayed for the former. On the other hand, if a heavy soil only was provided, egg-laying took place in this on every occasion. In this connection field observations in the Gezira district were of interest. The soil of this irrigated plain is a heavy clay. Eggs were laid by passing swarms continually over a period of 8–10 weeks, but only small bands of hoppers, and by no means many of these, were encountered later. There is no reason to suppose that the eggs failed to hatch, since no ordinary experimental soaking of eggs laid in such soil, such as would be given in crop irrigation, has at any time prevented their hatching. It is more probable that hatching did take place, but that the young larvae in many cases were unable to find suitable food in time and perished. As will be seen later, larvae can maintain only a very brief existence on unsuitable food.

Incubation Period.

The length of the period between egg-laying and hatching was noted for egg-pods laid by immigrant swarms and for three succeeding generations bred in the insectary, or for a period from September to January. The averages of these observations are as follows :—

Month	Number of observations	Average	Minimum	Maximum
September	29	13·4	12	16
October	5	12·8	12	13
November	38	14·9	11	18
December	21	22·8	15	25
January	7	17·8	14	21

The average time increased somewhat in December, a fact that may be attributed to a drop in temperature during the period.

The effect of various degrees of moisture in the soil was tested. Eggs were laid in sand which was kept saturated. These hatched in 20 days, that is, 7 days after those kept in drier sand. Eggs were laid in sand the surface of which had been moistened to a depth of one inch. Of three lots thus laid, one hatched in 12 days, another in 13 days, and the third did not hatch. On the other hand, attempts to induce oviposition in sand moistened to the depth of a few millimetres only failed. Numerous trial holes were dug, but the eggs were finally deposited on the floor of the cage. It was noted, however, that as soon as a shower of rain fell on this sand, oviposition took place shortly after.

A close connection probably exists between soil temperature and the length of incubation. Egg-pods laid in sand were maintained at a temperature of 15—18° C. The average period for ten egg-pods was 36·4 days with a maximum of 39 and a minimum of 34 days. The controls kept at room temperature and a soil temperature of 20—25° C. hatched in an average period of 20 days.

It was noted that a much higher proportion of eggs hatched in soil kept from drying out than was the case where soil was allowed to desiccate. Small battery glasses 7·5 × 4 cm. were used for egg-laying and were inserted into the floors of the cages. Those containing eggs were removed and similar glasses inverted over them, held

by adhesive tape. This prevented evaporation, and 95 per cent. of the egg-pods thus treated hatched. Where no attempt was made to prevent desiccation, hatchings were reduced to 24 per cent.

No indications have been found of a diapause in the egg stage.

Habits of Larvae.

Hatching indoors has been noticed to take place almost invariably between 7 a.m. and noon, most often between 8 a.m. and 10 a.m., never during the night. Of the few emergences noticed in the field, all were in the morning.

The process of hatching corresponds essentially to that described for this locust by other authors. The shedding of the embryonic skin (=intermediate moult of Uvarov) takes place usually on the surface at the exit of the tube, though in many cases skins are found in the tube itself. The larva usually reaches the top carrying the shrivelled skin on the apex of the abdomen or hind legs. It is shed by a deft movement of the body and the larva crawls away. The colour is pale, but darkening takes place at once, starting from the head. The final condition is attained in a little over half an hour. This darkening is accompanied by a hardening of the body coat, the pronotum gaining its arched shape and the parts of the legs straightening.

Feeding usually is only occasional during the first 24 hours, but larvae in the sunlight show more activity and commence feeding before those kept in the shade.

Great discrimination is shown in the feeding habits of the larvae. In the Gezira area the main crops grown are cotton, lubia (*Dolichos lablab*) and dura or millet (*Sorghum vulgare*). Newly emerged larvae given either of the first two all died within 48 hours. Those fed on dura normally reached maturity. It is believed that larvae emerging at some distance from their food-plant and not reaching it within two days will die. This, it is believed, accounts for the paucity of swarms on the irrigated cotton land.

In order to observe the effects of the transfer of older larvae from their proper food-plant to cotton and lubia, third stage larvae were so treated, others being given dura (their normal food). A very common weed, *Ipomoea* sp. (Arabic : Tabr), was included, since bands of larvae were frequently found resting on this plant. Eleven days later all were examined and weighed with the following results :—

Date	Food-plant	Total length	Weight of individual hopper	——
29.ix.30 ...	Cotton	26 mm.	0·375 gr.	All dead on 8.x.30
	Ipomoea	26 mm.	0·333 gr.	All dead on 5.x.30
	Lubia	24 mm.	0·270 gr.	All dead on 9.x.30
	Control (*Sorghum*)	32·5 mm.	0·625 gr.	All matured normally.

It is seen that whereas all larvae fed on *Sorghum* reached the adult condition, the others all died ten days or less after being transferred to the new food.

Observations in the field confirm the belief that wild grasses and graminaceous crops form the exclusive food of these locusts. On many occasions swarms were seen to alight near growing crops. All these were avoided, with the exception of dura or allied grains, and feeding was usually confined to low grasses. It may be taken therefore that the food of the larvae is exclusively plants of the order Graminaceae.

The two crops, dura (*Sorghum vulgare*) and dukhn (*Pennisetum typhoideum*), were frequently heavily damaged throughout the country. In some cases plants were

eaten almost to the ground level, and in others, stems were attacked and eaten through, the plants then collapsing and withering.

Feeding was observed at all times of the day, but was usually discontinued during the hours of highest temperature. Hoppers generally descended to the ground from the taller vegetation about one hour after sunrise. General movements of bands do not take place till much later. By disturbing parts of a large band in the morning before 8 a.m. a partial movement could be induced, participated in by the nearest portions of the band. This, however, usually stopped after a few minutes, but later in the day such induced movements might become general.

The great sensitiveness of larvae to movement is very noticeable, and appears to be greater in this locust than in others. Slight but quick movement of the head of a person lying on the ground at 15 feet distance would always produce negative response in hoppers, and such movements if continued might cause marching to commence by a portion of a band. Movements made slowly or at greater distances produced no response.

Feeding by winged individuals may begin very soon after the last moult. It has been observed as soon as 12 hours after moulting.

Description of Larvae.

It is not known that any description has been given of the larvae from known *L. migratorioides* parents in Africa. For this reason the stages are described here, but it will be noted that these correspond closely to those studied by Pratt and Zolotarevsky.

1st Stage Larva.—General appearance to naked eye black or very dark brown, with a white line down the centre from behind the head to apex of abdomen.

The head jet black on vertex; frons and mouth-parts of lighter colour. Pronotum lighter on sides. Legs very dark brown, with obscure scattered lighter markings; tibiae unicolorous black. The appearance is remarkably uniform in this stage.

2nd Stage.—The distribution of colours becomes more sharply defined in this stage. The median white line on pronotum becomes a distinct low keel. The line behind the eye joins a white streak on the anterior edge of the pronotum.

Head with vertex black; a brown line running back from the eye bounds this black area on either side and separates it from the epicranium and gena, which are mottled light and dark orange-brown. Frontal portions of head same colour; antennae brown; mouth-parts brown. Thorax with disk of pronotum sooty black; distinct keel with fine white line and cut by two sulci; lateral lobes brown, mottled as on head; meso- and metanotum dull brown. Abdomen dorsally black, with median ridge. Legs: first and second pair dark, with few obscure brown markings; hind femora and tibiae lighter brown-orange. To the naked eye the main impression of this stage is given by the black disk of the pronotum sharply defined against the lighter lateral parts of the body.

3rd Stage.—Similar to the preceding stage, but the colour of lower parts of body have become lighter.

Head with frons and mouth-parts yellow-brown or orange-brown; antennae dark brown; vertex shining black in front, further back dull black with two bright velvety lines; eyes black; the conspicuous line running from eye to pronotum has become faint orange bounded by black. Pronotum above shining black; keel distinct and straight, not convex; front margin with three or more white marks; keel and hind margin with orange lines; lateral lobes orange marked with black spots. Rudimentary wings dull black and covering the mesonotum. Abdomen very dark with several lines of white markings. Legs orange-brown with black spots, particularly on femora; tarsi darker.

4th Stage.—As third, with more conspicuous markings.

5th Stage.—As preceding stage. The hind femora may become lighter in colour, and the black area on the head may be invaded by surrounding yellow spots.

Relationship of Solitary and Gregarious Phases.

As has been shown above, very strong differences exist between the phase *solitaria* and *L. migratorioides* in both external appearance and structure. In order to find out how far, by the simple process of varying the numbers reared in cages, a continuous series of individuals could be obtained joining these two extreme forms, larvae from eggs laid by immigrant *L. migratorioides* were kept under observation. Seven varying degrees of crowding were chosen, namely, single hopper, pairs, threes, fours, nines, twenties and fifties. A maximum degree of overcrowding was provided by rearing further batches of larvae in lamp-glasses instead of in cages. Summarising the information obtained, it may be stated that hoppers reared singly invariably produced typical *solitaria* adults, but in the case of those crowded the adults approximated to their parents, but did not fully resemble them in structural details. The great majority were nearer to *L. migratoria.* Moreover, by rearing three succeeding generations under similar conditions no forms nearer to the original parents have been obtained. Changes of colour to green took place at various times during the larval period, but more usually at the 3rd or 4th moult. Very little variation was observed in the length of the larval period, which ranged from 23·1 to 24·6 days. The main facts may be tabulated as follows. The measurements of the adults are given in Table VII.

TABLE VI.

Effects of Crowding on Colours of L. migratorioides.

Number together	Hoppers		Adults
	Green	Not green	
Reared singly	54	4	All green except 4. Typically *solitaria*, except for a slight rounding of pronotal hind angle.
Reared in pairs	16	4	Greater proportion of brown individuals.
Reared in threes ...	4	17	Still greater proportion of brown individuals.
Reared in fours	2	26 Mostly swarming coloration	No green individuals; pronotal keel lower; all hind angles rounded.
Reared in nines	No green intermediate in colour		Keel high but straight in profile; black pronotal marks begin to appear.
Reared in twenties ...	All swarming colour		Keel lower and straight.
Reared in fifties ...	All swarming colour		Keel low and straight

Transformation to Phase solitaria.

The transformation of individuals of the swarming phase to the solitary phase has been repeatedly performed, and there is no question as to the possibility of swarms reverting to the solitary condition. In 1924 and 1926 individuals of the phase *gregaria* resembling *L. migratoria*, which had been obtained by the crowding of the larvae

TABLE VII.

Showing Measurements of Locusts from Hoppers bred in Cages.

Locality	Date	Particulars of specimens	Number of specimens	Total length	Length of elytra	Length of hind femur	Pronotum, length	Pronotum, breadth	Hind breadth	$\frac{F.}{H.F.}$	$\frac{B.P.}{B.H.}$
Khartoum	ix.1930	Bred from single *migratorioides*	9 ♂ 12 ♀	51·72 63·36	41·16 50·70	22·66 27·75	8·27 10·45	5·61 7·17	6·11 7·95	1·81 1·83	0·91 0·90
,,	,,	*migratorioides* in pairs	4 ♂ 6 ♀	53·75 64·75	43·12 52·91	23·50 28·08	8·75 10·41	6·12 7·41	6·62 8·25	1·83 1·88	0·91 0·89
,,	,,	*migratorioides* in threes	6 ♂ 4 ♀	53·25 61·62	42·83 50·00	22·58 25·87	8·41 9·75	5·91 6·87	6·50 7·50	1·88 1·93	0 90 0·91
,,	,,	*migratorioides* in fours	8 ♂ 6 ♀	52·06 61·08	41·31 48·50	22·75 26·33	8·62 10·33	5·87 7·00	6·62 7·83	1·81 1·84	0·88 0·89
,,	,,	*migratorioides* in nines	3 ♂ 4 ♀	55·33 66·50	43·83 53·50	24·33 28·75	8·50 10·75	6·00 7·50	6·66 8·25	1·80 1·86	0·90 0·90
,,	,,	*migratorioides* in twenties	3 ♂ 11 ♀	56·00 61·40	44·50 49·04	23·16 25·36	8·25 9·36	5·86 6·77	6·63 7·81	1·91 1·93	0·88 0·86
,,	,,	*migratorioides* in fifties	20 ♂ 20 ♀	52·62 59·60	42·35 47·72	22·00 24·72	8·12 9·15	6·57 6·60	6·70 7·52	1·92 1·93	0·98 0·87
,,	,,	Crowded in lamp-glasses	5 ♂ 2 ♀	51·00 62·00	40·66 49·75	21·40 25·75	7·50 9·25	5·60 6·75	6·30 7·75	1·89 1·93	0·88 0·87

of *L. danica*, were allowed to breed, and certain of the larvae were reared singly. These produced typically solitary adults, whereas those from crowded larvae resembled the parents. It remained, however, to ascertain whether, if the gregarious phase reached the swarming migrant stage, the transformation back to the solitary condition would still be possible. The opportunity for testing this came with the arrival of swarms of *L. migratorioides*. Eggs laid by these in the field were dug up and others were obtained from females in cages. The hoppers were separated out at each of the stages and reared singly. A very high degree of plasticity was found to exist as regards colour, since larvae separated even after the 4th moult (*i.e.*, in the 5th stage) turned green in 25 per cent. of the cases observed. Those left crowded retained the swarming coloration. It was found that the numbers of those turning green was approximately inversely proportionate to the age at the time of separation.

On several occasions search was made in the field for larvae of the phase *solitaria* for comparison with those reared in cages. These were found on various dates during September and October. Localities were particularly chosen where poisoning of hoppers had not been carried out.

The habitat favoured by the solitary phase was among *Cymbopogon* and other tufted grasses. Sweeping and search gave about a dozen larvae an hour, and they could not be described as common. On comparison with cage-reared individuals no difference whatever could be discerned.

On crowding these hoppers taken in the field, a very definite *congregans* phase was obtained in the swarming-coloured larvae, and some remained green. Moreover, the adults were brown in the majority of cases and closely resembled the forms obtained in the Red Sea district in 1926.

Interbreeding of L. *danica* and L. migratorioides.

On several occasions this was observed during the passage of swarms, females of the former being taken *in copula* with males of the latter. The resulting hoppers were reared together, and it was found that the adults differed in no essential manner from those obtained by crowding the hoppers of *L. migratorioides*.

The authors wish to record their thanks to Mr. G. W. Grabham, Government Geologist, for obtaining the rainfall records mentioned in this paper.

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NEW INJURIOUS CURCULIONIDAE (COL.).

By Sir Guy A. K. Marshall, C.M.G., D.Sc., F.R.S.

(Plate XXI.)

Subfamily Brachyderinae.

Aedophronus echinatus, sp. n. (Pl. xxi, fig. 2).

Derm black, with dense brown scaling, usually with an indefinite mottling of darker and paler scales; the inflexed margins of the elytra fuscous.

Head not very convex, with the median stria extending to the vertex and the anterior transverse stria slightly curved; the infra-ocular margin much narrower than the base of the scape and not projecting; the setae short, stout and curved backwards; the eyes comparatively large, highest much behind the middle, and with the hind margin devoid of scaling. *Rostrum* longer than the head (5·5 : 4), much shorter than its basal width (5·5 : 7·5), narrowed in front, straight at the sides, with a shallow impression on the apical half and with no median carina; the marginal carina of the epistome obtuse but distinct. *Prothorax* transverse (3·5 : 6), strongly rounded at the sides, widest at the middle, subtruncate at the apex, which is only slightly narrower than the base; the dorsum with an abbreviated median stria on the basal half and bearing on the disk short curved setae like those on the head, the lateral ones much longer, stout, straight and pointed (when unbroken), the longest being about as long as the scape. *Elytra* broadly oval, obtusely rounded behind, shallowly sinuate at the base, with distinctly punctate shallow striae; the setae not very dense, but very long and sharp at the sides and apex, those on the basal half of the disk much shorter. *Legs* with dense brown scaling and coarse subrecumbent setae; the front tibiae with an apical row of 4–6 spines and two on the external edge.

Length, 3·6–4·6 mm.; breadth, 1·8–2·4 mm.

Transvaal: Leydsdorp Road, 7.x.1927.

Described from five specimens, bearing the note that the adult weevils were feeding on the young shoots of newly planted almond trees.

Most nearly allied to *Æ. setosus*, Fhs. 1871, which differs in its more numerous, much shorter and truncate setae, the lateral ones on the prothorax being only about half the length of the scape, and in the absence of the bare patch behind the eyes.

Mimaulus sulcatifrons, sp. n. (Pl. xxi, fig. 4).

Derm black, with dense grey scaling which is more or less discoloured by a brownish exudation, especially along the striae on the elytra.

Head with three longitudinal sulci of equal width (normally filled with exudation), the intervals with dense scaling and short appressed setae; the supra-ocular ridge scarcely developed into a callus above the back of the eye, and the hind margin of the latter rounded off and not forming an angular projection. *Rostrum* almost as long as its basal width, longer than the head, with four broad shallow longitudinal sulci on the basal half, of which the median pair converge strongly behind; the apex gradually declivous, with the margin of the epistome sharply carinate and forming an acute angle behind, its anterior angles sharply prominent; the genae with a broad longitudinal impression, usually filled with secretion; scaling and setae as on head. *Prothorax* slightly more than twice as broad as long, moderately rounded at the sides, widest close to the base, shallowly constricted at the apex, with the apical margin truncate and the base arcuate; the dorsum closely set with completely flattened granules, on which the scales form a rosette round a short appressed seta, and with a feeble median stria. *Elytra* broadly oblong-ovate, widest rather behind the middle,

jointly sinuate at the base and there as wide as the widest part of the prothorax, with shallow striae in which the punctures are partly concealed by scaling and secretion; the intervals each with a row of very short, obliquely raised, inconspicuous setae. *Legs* with dense scaling and long erect setae; the front tibiae with the apical margin transverse and bearing only two spines in addition to those at the angles.

Length, 4·0–4·8 mm.; breadth, 2·7–3·1 mm.

TRANSVAAL: Zoutpansberg, destroying young cotton, i.1920 (*type*); Limburg, near Piet Potgietersrust, on tobacco, x.1927.

Described from twelve specimens.

Differs from all the previously described species of *Mimaulus* in its trisulcate head and rostrum, and in the prominence of the apical angles of the epistome. It is extremely similar in facies to *M. papulosus*, Fhs. 1871, which differs, in addition to the characters just mentioned, in having a distinct callus above the eye and the hind margin of the eye sharply angulate (as seen from above); the margin of the epistome is broadly rounded behind and not carinate; the front tibiae have three teeth on the apical margin; and the head and rostrum, when scraped, are set with small cylindrical tubercles, which are normally quite concealed by indumentum, the apex of each tubercle bearing a rosette of scales; the pronotum has similar concealed tubercles.

M. papulosus has been received only from Middelburg and Louis Trichardt, in the Transvaal, where it was found eating tobacco leaves and destroying the seedlings.

Subfamily OTIORRHYNCHINAE.

Lalagetes leurops, sp. n. (Pl. xxi, fig. 1).

Derm black or piceous, with dense grey or pale brown scaling, with an opalescent reflection; prothorax usually with a very indefinite paler median stripe and a much broader bilateral one, beneath which is a broad dark stripe on the pleurae; elytra usually with an indefinite sublateral paler stripe continuous with that on the prothorax, and the alternate intervals with irregular blackish patches (sometimes indistinct or obsolete).

Head with the eyes quite lateral and almost flat; the forehead flat, parallel-sided, with dense erect scales and sparse suberect spatulate setae. *Rostrum* as long as broad, a little longer than the head, with the dorsal area parallel-sided in the middle, widening at the base and longitudinally impressed; the scrobes comparatively narrow, not entirely exposed from above, terminating at some distance in front of the eyes. *Antennae* with the scape very stout, only slightly clavate, strongly bent below the middle, densely squamose, and with stout recumbent setae; the funicle with joint 1 somewhat longer than 2, 3 slightly longer than 4, 4–7 subequal and about as long as broad. *Prothorax* transverse (3 : 2), rounded at the sides, widest behind the middle, strongly constricted at the apex and the dorsal apical area depressed; the dorsum very shallowly depressed in the middle of the basal two-thirds and with a deeper rounded impression on each side, with dense overlapping scales and scattered dark subrecumbent spatulate setae. *Elytra* very broadly ovate, almost parallel-sided in the middle, jointly sinuate at the base broadly rounded behind, the sides almost straight for a short distance from the basal angle, but without any definite subhumeral angulation; the striae narrow, with the shallow punctures quite concealed by the scaling; the intervals each with a row of dark subrecumbent spatulate setae, the alternate ones (1, 3, 5, 7) slightly more raised, especially at the base and behind the middle. *Legs* stout, with dense opalescent grey scaling and broad subrecumbent setae, the femora with a variable large dark patch; the tibiae rather broadly dilated at the apex, the front pair with the outer apical angle produced and bearing a stout duplicated spine; the tarsi densely squamose above.

Length, 4·0–4·2 mm. ; breadth, 2·3 mm.

CAPE PROVINCE : Wynberg, Cape Town, ix.1900.

Described from six specimens. The adult weevils were found feeding on grape vines.

Distinguished from all previously described species of the genus by its flattened eyes, parallel-sided forehead, apically dilated front tibiae and densely squamose tarsi.

Subfamily EREMNINAE.

Catoptes instabilis, sp. n.

♂♀. Derm black or piceous, with dense scaling that is very variable in colour ; usually irregularly mottled with various shades of brown and grey, sometimes almost entirely brown or almost entirely grey, the browns being normally much darker in ♂ than in ♀, and nearly always with some trace of the characteristic V-shaped pale marking at the top of the declivity ; in two ♂♂ the brown spots have united to form three regular dark stripes on each elytron (var. **vittiger**, n.) ; underside uniformly grey.

Head with the frontal fovea concealed by scaling ; the eyes almost flat, their curvature continuous with that of the head. *Rostrum* much longer than its apical width, almost parallel-sided in the basal half and markedly dilated at the apex ; the dorsum, viewed from the side, quite flat behind the antennae, without any trace of a median carina. *Antennae* red-brown ; the scape straight and strongly clavate ; the funicle with joint 1 as long as 2+3, 3 somewhat longer than 4 and both a little longer than broad, 5–7 moniliform and slightly transverse. *Prothorax* about as long as broad, rounded laterally, widest at the middle, scarcely constricted at the apex ; the dorsum transversely convex in ♀, more flattened in ♂, quite smooth, densely squamose, and with short subrecumbent setae. *Elytra* ovate, subparallel for a short distance about the middle, narrower in ♂, jointly sinuate at the base, obtusely acuminate behind ; the shallowly punctate striae completely hidden by scaling, the punctures without any noticeable seta ; the intervals all even, each with a somewhat irregular row of short dark subrecumbent setae, ints. 1, 3, 5, 7 with a few conspicuous white setae posteriorly. *Legs* reddish, with the femora piceous ; the inner edge of the front tibiae scarcely denticulate ; joint 2 of the tarsi transverse.

Length, 3·5–4·0 mm. ; breadth, 1·7–1·8 mm.

NEW ZEALAND : Central Otago, 9♂♂, 11 ♀♀, on turnips.

Closely allied to *C. argentalis*, Brn., the female type of which is a narrower insect (3·8×1·5 mm.), and has the rostrum scarcely dilated at the apex, distinctly curved dorsally, and with an abbreviated median carina ; joints 3 and 4 of the funicle are equal and moniliform.

Another closely related species is *C. aequalis*, Brn., in which the rostrum is similarly shaped, but bears a distinct median carina ; the scape is longer, extending well behind the eye (in *instabilis* it reaches only the hind margin of the eye) ; the prothorax is widest in front of the middle ; the striae and punctures on the elytra are partly visible through the scaling, and the setae are suberect.

Catoptes fraudator, sp. n.

♂♀. Very similar to paler specimens of the preceding species, though noticeably smaller, and differing in the following characters :—

Head with the eyes distinctly convex. *Rostrum* much shorter, only slightly longer than broad, narrowing from the base to the middle and scarcely dilated at the

apex; the epistome markedly asymmetrical, the right side projecting beyond the mandibles and with its margin broadly rounded. *Antennae* with the scape slightly curved; joint 3 of the funicle not longer than 4. *Elytra* with the position of the punctures indicated by a narrow white scale.

Length, 3·1–3·25 mm.; breadth, 1·3–1·5 mm.

NEW ZEALAND: Central Otago, 2 ♂♂, 1 ♀, on turnips.

From this species *C. argentalis*, Brn., differs *inter alia* in its much longer carinate rostrum and flattened eyes.

Catoptes postrectus, sp. n.

♂♀. Derm black or piceous, with dense grey scaling, sometimes variegated with darker markings and usually with a dark spot on interval 3 of the elytra near the declivity.

Head with the frontal fovea concealed by scaling; the eyes quite flat and placed rather lower than usual, so that the forehead is fully as broad as the base of the rostrum. *Rostrum* longer than its apical width, parallel-sided in the basal half, with the genae moderately dilated and the emargination of the epistome almost symmetrical; the dorsum set with stiff suberect dark setae and without any median carina. *Antennae* red-brown; the scape slightly curved, gradually clavate and not exceeding the hind margin of the eye; the funicle with joint 1 equal to 2+3, 3–7 subequal, moniliform and transverse. *Prothorax* as long as broad, moderately rounded laterally, widest at about the middle, feebly constricted at the apex, and with the posterior angles rounded off; the postocular lobes very feeble; the dorsum somewhat flattened in both sexes, quite smooth, densely squamose, and with sparse short stout dark suberect setae and a few whitish ones. *Scutellum* minute, with dense whitish scaling. *Elytra* oblong-ovate, only slightly narrower in the ♂, jointly sinuate at the base, obtusely acuminate behind, with the sutural area compressed and elevated, at the top of the declivity, so that the dorsal outline is quite flat and becomes abruptly perpendicular on the declivity in both sexes; the striae and punctures entirely concealed by the scaling; the intervals with subrecumbent compressed setae, which are more numerous on the alternate ones, especially at the summit of the declivity on intervals 1 and 5; the setae mostly dark on the disk, but white ones predominating towards the sides and apex. *Legs* densely squamose, with the tarsi piceous; the front tibiae somewhat curved towards the apex and scarcely denticulate internally; the tarsi with joint 2 strongly transverse.

Length, 2·5–3·0 mm.; breadth, 1·3–1·4 mm.

NEW ZEALAND: Oamaru, 6 ♂♂, 5 ♀♀, on mangels, 1930 (*J. Muggeridge*).

Distinguishable from its congeners by its small size, unusually wide forehead, and perpendicular elytral declivity.

Subfamily ITHYPORINAE.

Diaphna nociva, sp. n. (Pl. xxi, figs. 3, 3*a*).

♂♀. Derm black, with dense brown scaling variegated with lighter and darker markings; head uniformly brown; prothorax with a narrow paler median line, a pale dot adjoining it on each side in front of the middle and usually two more on each side near the front margin; elytra brown, with irregular blackish and sometimes paler patches, and just above the posterior declivity a conspicuous transverse lenticular pale patch extending to interval 3 on each elytron, sometimes produced slightly along the suture anteriorly but not posteriorly, where it is followed immediately by a velvety sutural black patch extending half way to the apex and reaching interval 2 on each side; underside with uniform dense fulvous scaling.

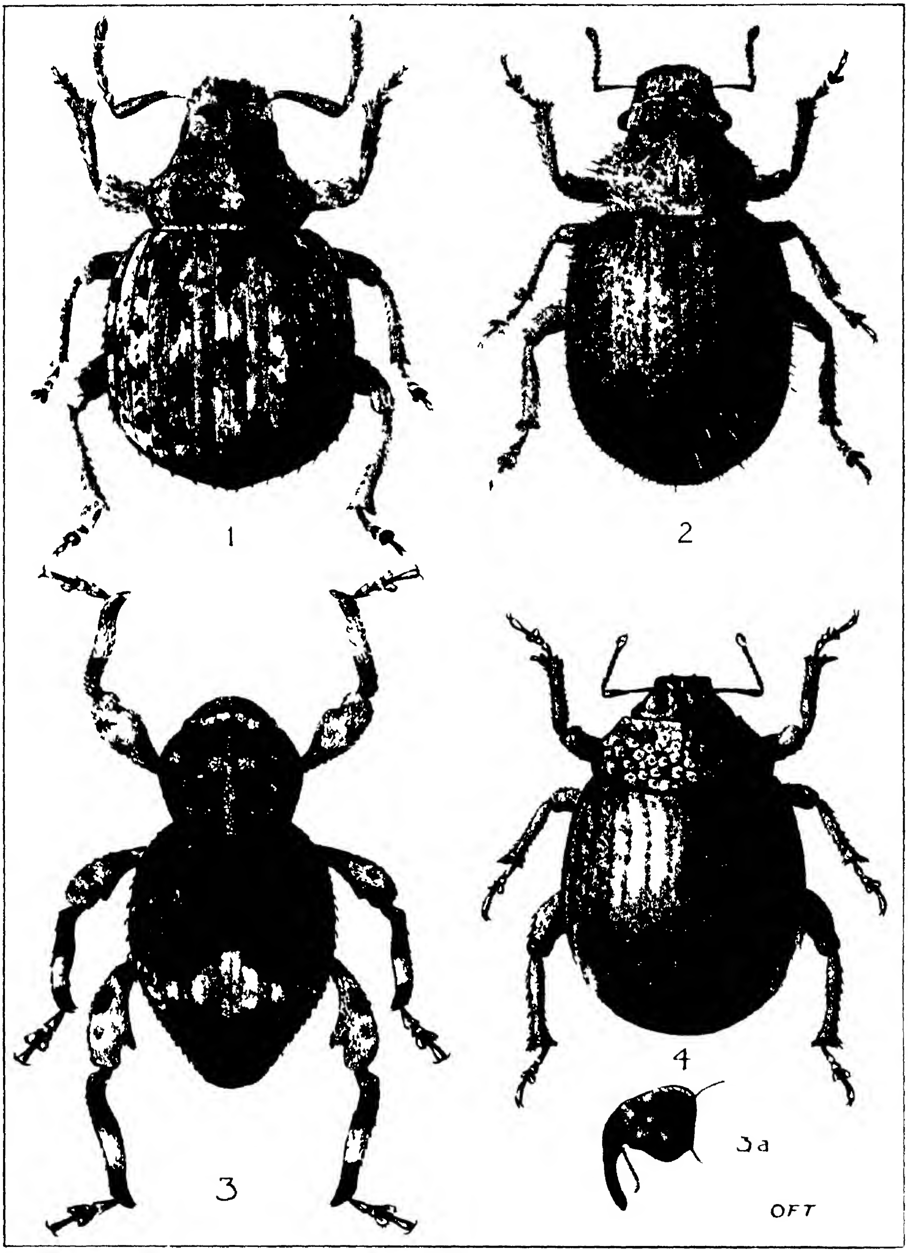
Head with rather fine reticulate punctures, the forehead flattened. *Rostrum* of ♂ curved, rather slender, gradually narrowing from the base to the middle and thence parallel-sided, with five carinae on the basal two-thirds, the outer pairs being narrower and undulating, the apical area finely punctate in rows ; of ♀, slightly dilated at the apex, coarsely punctate on the basal third, with the outer pairs of carinae obsolete and the median one distinct only at the extreme base. *Antennae* with the funicular joints in order of length : (1, 2), (3, 4), 5, 6, 7 ; 7 slightly transverse, 6 as long as broad, the rest longer than broad. *Prothorax* about as long as broad, strongly rounded at the sides, widest in front of the middle, the subapical lateral constriction inconspicuous from above ; the base truncate, the apex strongly arcuate ; the dorsum strongly convex, with dense reticulate punctures that are not confluent laterally, with an obtuse squamigerous median carina on the apical third and a transverse depression on each side of it ; every puncture containing a broad scale lying transversely. *Elytra* ovate, widest before the middle, rather sharply acuminate at the apex, and with broad sulci set with large remote punctures that are conspicuous through the dense scaling ; the intervals narrower than the sulci, costate and each with a row of low shiny granules bearing a recumbent scale-like seta, except int. 1 which is flat throughout and has a few small granules in the basal half only ; ints. 3 and 5 more raised at the base (3 being rather the higher) but not projecting forwards beyond the basal margin, and 2 the highest at the top of the posterior declivity. *Legs* with mottled pale and dark brown scaling which hides the sculpture ; femora with an ill-defined dark patch, the front pair not dentate ; tibiae dark at base and apex and pale in the middle, with the inner edge strongly bisinuate and the dorsal edge of the hind pair sinuate, the outer apical angle of the latter obliquely curved.

Length, 5·1–6·0 mm. ; breadth, 2·4–2·8 mm.

CAPE PROVINCE : George, 3♂♂, 3 ♀♀, iv.1931.

This insect is reported as doing serious injury to pine trees (*Pinus*), the larvae boring under the bark and partly into the wood.

Its nearest ally is *Diaphna* (" *Ithyporus* ") *odiosa*, Boh., which differs *inter alia* in having a much stouter, parallel-sided rostrum ; joints 3–7 of the funicle are moniliform and transverse ; the pronotum is somewhat flattened dorsally and the punctures confluent, so that the intervals form numerous oblique or longitudinal carinae ; the transverse pale patch on the elytra is situated further back, on the declivity ; and the outer apical angle of the hind tibiae is roundly rectangular.



New South African Curculionidæ.

Fig 1 *Lalagetes leurops* sp n   Fig 2 *Ædophrorus echinatus* sp n
Fig 3, 3a *Diaphna nociva* sp n   Fig 4 *Mimaulus sulcatifrons*, sp n

A NEW SPECIES OF WARBLE-FLY (DIPTERA—FAMILY TACHINIDAE, SUBFAMILY HYPODERMINAE, GENUS *HYPODERMA*), WHICH ATTACKS GOATS IN CYPRUS.

By Major E. E. AUSTEN, D.S.O.

Adult insects belonging to the genus *Hypoderma*, all species of which in their larval stages are parasitic in Ungulates, fall naturally into two groups. In the first of these, represented by *Hypoderma bovis*, De G., *H. lineatum*, Vill., and *H. diana*, Br., the body is conspicuously hairy, and the dorsum of the main portion of the thorax (scutum) is marked with a series of shining black, raised stripes or longitudinal wheals. In the second group, to which belong *H. silenus*, Br., *H. crossi*, Patton, *H. corinnae*, Crivelli, and doubtless also *H. aegagri*, Br., the hairy covering of the body is sparser and less noticeable, and the dorsum of the thorax is devoid of the markings just mentioned. The species to be described below forms an addition to the second group.

Genus **Hypoderma**, Latr.

Hypoderma aeratum, sp. nov. (figs. 1, 2).

♂♀. Length, ♂ (one specimen), 11·6 mm., ♀ (three specimens), 10·25 to 10·8 mm.; width of head, ♂ just under 4 mm., ♀ 3·2 to 3·5 mm.; width of front (frons) at vertex, ♂ 0·6 mm., ♀ 1·25 to 1·5 mm.; length of wing, ♂ 8·6 mm., ♀ 7·5 to 8 mm.

Small species, at least in ♀ sex, with dorsum of thorax dark olive, and that of abdomen old-gold-coloured or brassy, marked according to angle of incidence of light with paler or darker, large quadrate, shimmering patches or interrupted transverse bands; dorsum of thorax showing inconspicuous longitudinal stripes, but with no trace of the shining black, raised stripes or longitudinal wheals exhibited by* Hypoderma bovis, *De G.*, H. lineatum, *Vill., and* H. diana, *Br.*

Head: front in both sexes, except anterior border in ♀ (which is tawny, with a shimmering, light ochraceous-buff, pollinose covering), deep olive; frontal stripe in ♂ clove-brown posteriorly, tawny anteriorly; frontal stripe in ♀ more or less ochraceous-tawny or cinnamon-brown; front in ♂ narrowing posteriorly to less than half its width on anterior margin; front in ♀ somewhat narrower in middle than anteriorly and on vertex; ocelli in same sex appearing tawny or russet; facial shield (light buff pollinose in both sexes), viewed from in front, elongate in ♂, rounded below and with somewhat sinuous lateral margins; facial shield in ♀ slightly wider in middle in proportion to its length; jowls somewhat darker, especially below each eye, where they are tinged with ochraceous-tawny or ochraceous-buff; antennary pits slate-black; occiput, except posterior orbits, which are paler (narrowly so in ♂, more widely in ♀, in which they are light buff pollinose or cinnamon-buff), dark olive-grey above, with light neutral grey pollinose covering, and light buff below; front in both sexes clothed with fine, erect hairs—brownish mixed with ochraceous-buff in ♂, mainly ochraceous-buff in ♀; parafacials clothed with ochraceous-buff or ochreous hairs, face, jowls and greater portion of occiput clothed with glistening whitish hair which sometimes has a yellowish tinge, upper part of occiput thinly clothed with ochreous hair; ***antennae*** with third segment black, and arista, which is slender, tapering and relatively long, blackish-brown at base, then mummy-brown.

* For names and illustrations of colours used for descriptive purposes in the present paper, see Ridgway, "Color Standards and Color Nomenclature" (Washington, D.C. Published by the Author, 1912).

Thorax: longitudinal stripes on dorsum viewed from certain angles darker than surrounding ground-colour but inconspicuous, consisting of a slender admedian pair, appearing impressed and extending from anterior margin to less than half way between transverse suture and posterior border of scutum, and a broader stripe on each side, widely interrupted by suture and not reaching either front or hind margin of scutum; groove between scutum and scutellum, as also twin bosses forming hind border of latter, shining black, the bosses, at least in ♂, slightly pollinose; dorsum, including scutellum, in both sexes isabella-coloured pollinose; pleurae and pectus smoke-grey pollinose; dorsum of scutum clothed with short, brownish or blackish, backwardly directed hair (in ♀ largely replaced by similar old-gold-coloured hair), which on lateral borders is replaced by longer, glistening, old-gold-coloured hairs; dorsum of scutellum

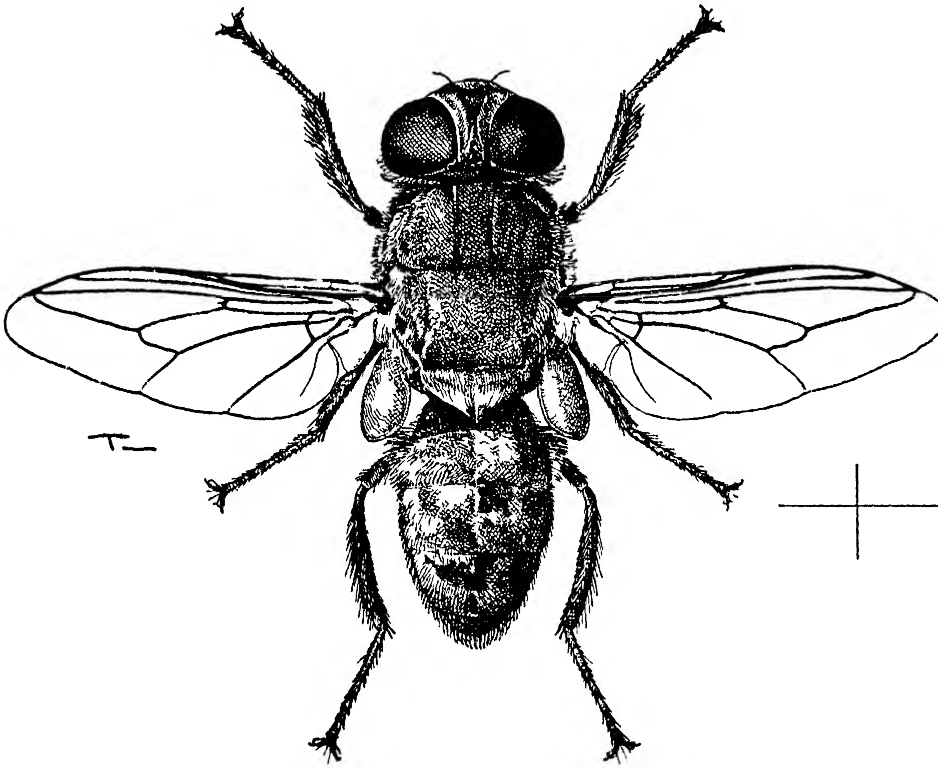


Fig 1. *Hypoderma acratum*, sp n, ♂ (×6)

clothed with old-gold-coloured hair, erect anteriorly, elsewhere appressed, backwardly directed and glistening, forming a pointed wisp of hair between bosses on hind border; meso- and sternopleurae clothed with backwardly directed hair, ochreous or old-gold-coloured in ♂, pearl grey in ♀ tinged with yellowish, and in both sexes especially dense on mesopleurae.

Abdomen: dorsum in ♂ and first four visible tergites in ♀ clothed with old-gold-coloured or ochreous hair, short and appressed in ♂ except on first visible tergite, longer on first four visible tergites in ♀, ♂ with some black hairs in middle of hinder portion of second visible tergite and with more numerous black hairs in corresponding region of the three following tergites, ♀ sometimes with a few black hairs similarly

placed on second visible and two following tergites; ovipositor in ♀ shining black, with a circlet of ochreous hairs on hind margin of fifth visible tergite; venter in ♂, and venter in front of ovipositor in ♀, neutral grey pollinose, thinly clothed with ochreous hairs.

Wings strongly tinged with drab, and with first posterior cell sometimes only very narrowly open or actually closed on margin. *Squamae* cream-buff or cream-coloured. *Halteres* (in dried specimens) cinnamon-rufous.

Legs cinnamon-rufous, coxae, trochanters and bases of all femora dark mouse-grey, or deep mouse-grey, a colour which on extensor or surface of front femora, with exception of extreme distal margin, extends to tip; flexor and inner and outer surfaces of front tibiae in ♂, except tips, and to a lesser extent corresponding area of hind tibiae in same sex, deep mouse-grey; front and hind tibiae in ♀ sometimes with a faint trace of similar infuscations; tips of first four tarsal segments of all legs in both sexes, especially when viewed by transmitted light, sharply infuscated; coxae and trochanters in

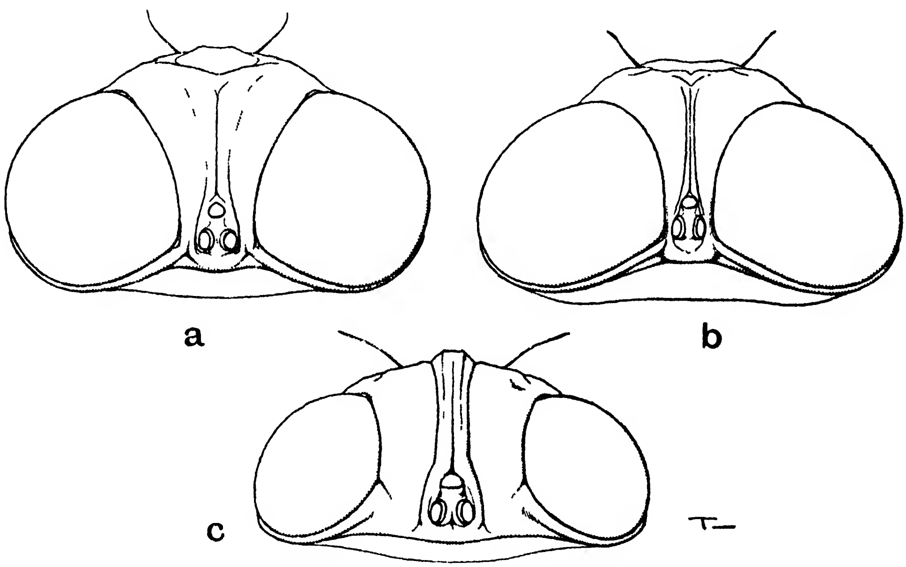


Fig. 2. Head of: (*a*) *Hypoderma aeratum*, sp. n, ♂; (*b*) *H. crossi*, ♂; (*c*) *H. aeratum*, ♀.

♂ clothed with ochreous or ochraceous-buff hair, hair of same colour also predominating in same sex on flexor surfaces of femora, and on extensor surfaces of hind tibiae; hair on legs in ♂ otherwise mainly black; hair on legs in ♀ for most part glistening ochraceous-buff or warm buff, mingled here and there, as on anterior surfaces of hind tibiae, with minute black hairs.

CYPRUS.

Type of ♂, *type* of ♀, from Kyrenia; larvae taken from warbles on a goat 22.ii.1930; adults emerged respectively 14 and 15.v.1930. Two ♀ paratypes, from Tylliria, bred from larvae from warbles on a kid, found on floor of latter's cage 14.i and 3.ii.1930; one adult found recently dead 12.v.1930, the other emerged 16.v.1930. All specimens collected by *H. M. Morris*, M.Sc., F.E.S., Government Entomologist, Cyprus, and presented by the Imperial Institute of Entomology.

From the allied *Hypoderma silenus*, Br., of southern Europe and the Mediterranean Subregion, the larva of which is perhaps parasitic in the domestic donkey, the species described above is distinguishable *inter alia* owing to the dorsum of its abdomen

shimmering golden or brassy instead of greyish, and by the hair clothing the abdominal dorsum being shorter and more appressed. *Hypoderma aeratum* is also allied to *H. crossi*, Patton, a larval parasite of goats in the Punjab,* but differs in being of somewhat larger size, in the front of the male at the vertex being wider (equal to rather more than two-fifths instead of one-third, of the length of the transverse diameter of the eye when the latter is viewed from above (*cf* fig 2, *a*, *b*), and in the tibiae being less strongly infuscated. Likewise nearly related to *Hypoderma aeratum* is *H. corinnae*, Crivelli (Mem R. Ist. Lombardo, ix, pp 67, 68, and figs., 1862), a parasite

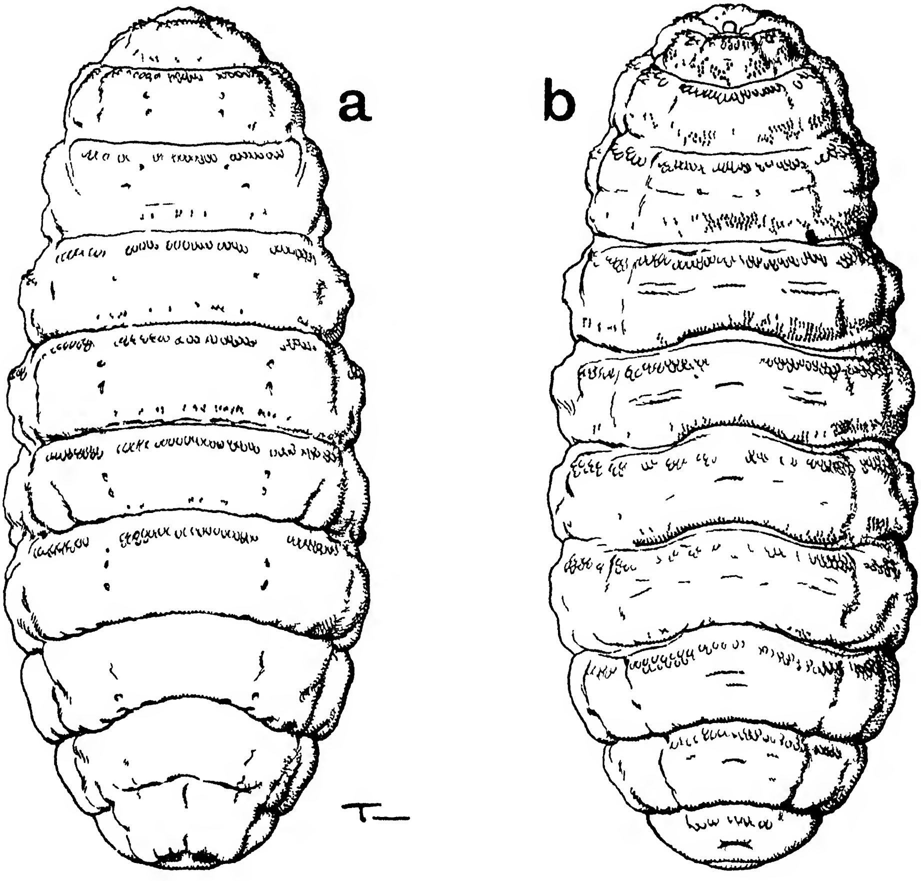


Fig 3 *Hypoderma aeratum*, sp n, fully grown larva, *a*, dorsal view *b* ventral view (x 6)

of *Gazella dorcas*, Linn, in Algeria, originally described only from the mature larva, the adult of which was unknown to the author of the species If the adult described and figured by Larrousse (Archives de l'Institut Pasteur d'Algérie, vii, pp. 218, 219, figs 1–3, 1929) from a female specimen from the region to the west of Biskra really

* Patton (The Indian Journal of Medical Research, x, p 573, 1922), in the title of the paper in which this species is described, speaks of it as parasitic in its larval stages in cattle as well as goats in the Punjab, but in the body of the paper no evidence is adduced to prove that the warble-fly of Punjab cattle is actually *Hypoderma crossi*.

belongs to this species,* the latter would appear to differ from *H. aeratum* at any rate in having the thorax narrower than the head, instead of the reverse, and clothed with longer hair ; the thoracal squamae white instead of cream-buff or cream-coloured ; and the abdomen greenish-brown instead of old-gold-coloured or brassy.

Larval stages of H. aeratum (figs. 3–5).

A long series of larvae, obtained from goats and kids and preserved in alcohol, was also sent home by Mr. Morris and is now in the British Museum. Of these specimens the two largest, which are apparently not quite mature, measure respectively just over 19 mm. and 17·5 mm. in length, by 9 mm. and 9·5 mm. in greatest width

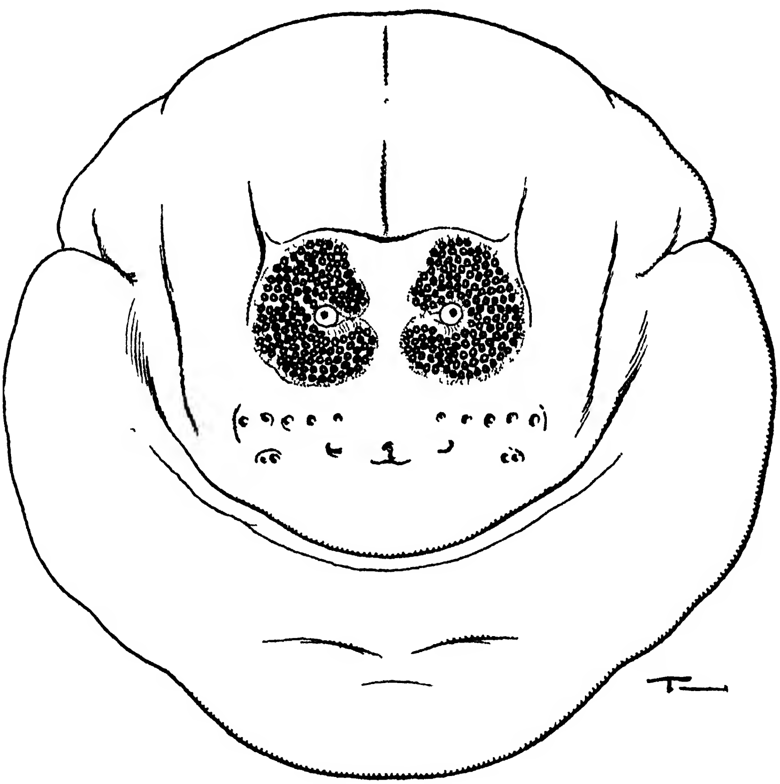


Fig 4 *Hypoderma aeratum*, sp n : spiracles of larva (x26)

(*i.e.*, across the seventh segment). The general coloration is cream-buff. Each segment from the second to the eighth inclusive bears, on or near its anterior border, and extending completely round the dorsal, lateral, and ventral surfaces, a compound ring of more or less fleshy, recurved, spine-like tubercles, some of which, on the second segment at any rate, have black, chitinous points. On the ventral surface the anterior border of each of the three following segments bears a transverse band of similar, spine-like tubercles, which, in the case of the penultimate and antepenultimate segments, extend on to the lower lateral swelling on each side. On the dorsal surface

* The length of the adult ♀ (20 mm) as given by Larrousse is obviously incorrect, especially seeing that this author (*t. cit.*, p. 218) states that the fly is " un *Hypoderma* de très petite taille."

each segment, from the second to the seventh inclusive, has a narrow, transverse, more or less compound posterior band of minute, forwardly directed spines, with black or blackish, chitinous tips. Ventrally the posterior borders of the second to the eighth segments inclusive, bear corresponding transverse bands of minute spines; on the second to the seventh segments inclusive these posterior ventral bands of spines are much *deeper*, *i.e.*, consist of many more transverse rows, than the corresponding bands of spines on the dorsal surface. In the case of the second to the seventh segments inclusive, the posterior bands of minute spines extend on to the area of the lower lateral swelling on each side. A comparison of the foregoing details, and of fig. 3, with Patton's figures (*t. c.*, p. 576, text figs. 2 and 3) of the nearly mature larva of *Hypoderma crossi*, Patton, will show marked differences between the two species. Differences are also presented by the posterior stigmatic

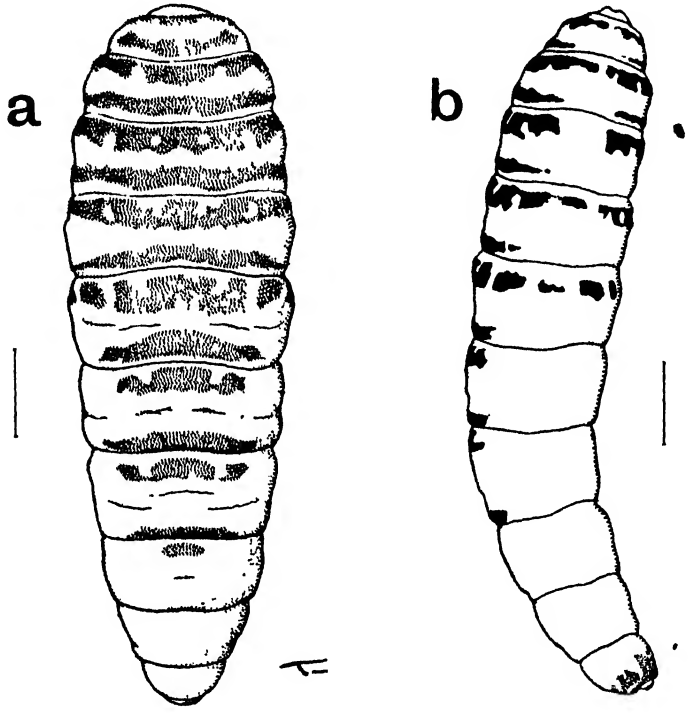


Fig 5 *Hypoderma aeratum*, sp n, young larva *a*, dorsal view, *b*, lateral view, showing arrangement of bands of spines (diagrammatic) (x8)

plates, the cribriform areas which make up each plate being apparently much closer together in the larva of *H. aeratum*, so that the plate itself has a more homogeneous appearance (cf. fig. 4 and Patton's text fig. 4, *t. c.* p. 578).

The nearly mature larva of *Hypoderma aeratum* resembles as regards its dimensions the corresponding larval stage of *H. aegagri*, Brauer,* but is distinguishable by the absence, on the lateral swellings and on the upper side, of transverse rows of small,

* *Monographie der Oestriden*, pp. 134–135, Taf viii, figs. 9, 9a, 1863. This species, based by its author on the 3rd stage larva only, was described from material obtained in the menagerie at Schönbrunn, Austria, in February and June, from ibexes (*Capra aegagrus*, Erxl.) newly arrived from Crete. The actual description is not preceded by a specific name, which however appears subsequently in the index (*op. cit.*, p. 281).

smooth, button-like warts, each provided with a pit. It is further distinguishable from the corresponding larva of *H. aegagri* by the posterior, dorsal, transverse bands of minute, forwardly directed spines being present on the second to the seventh segments inclusive, instead of ceasing on the fifth segment, and, in the median area at least of the posterior spinigerous segments, consisting of from two to three rows of spines instead of only a single row.

Larvae of *Hypoderma aeratum* in a considerably younger stage, such as for instance measure 10 mm. to 12·25 mm. in length, by 2·25 to 4·25 in greatest breadth, are entirely devoid of rings of fleshy, recurved, spine-like tubercles. On the other hand, in such specimens the body bears numerous and very conspicuous transverse bands, each of which consists of a number of rows of minute, black, chitinous spines. The second to the fifth segments inclusive are each more or less completely encircled by a band of this kind near the anterior margin, and have a similar band in front of the hind border. On the sixth segment there is a complete band only on the fore border, the band in front of the hind margin being confined to the ventral surface. The seventh to the tenth segments inclusive are devoid of bands on the dorsal surface; ventrally the seventh to the ninth segments inclusive each have a posterior as well as an anterior band of spines. The tenth segment is entirely without spines ventrally as well as dorsally (*cf.* fig. 5, *a*, *b*).

The British Museum (Natural History) has long possessed several pieces of goat-skin from Cyprus, heavily warbled by mature or nearly mature larvae of the present species. These specimens, accompanied by the following note, were presented in January, 1900, by Mr. P. Gennadius, at that time Director of Agriculture, Cyprus.

"The subcutaneous larvae in goats are called by Cypriotes ἀδάρια. They are very common on goats from one to two years old, less common on those from three to four years old; common also on cattle; rare on sheep and shepherds' dogs. When goats are slaughtered and skinned during the month of June these larvae are rare and small. From the month of July they are numerous, though still small. When found in November, and especially in December, they are nearly fully grown, as in the specimens forwarded.

"From the month of February the number of tumours in the skin of an infested animal begins to diminish, and they entirely disappear towards the end of March, when the shepherds of the island say that their goats get *cleaned*, because they eat green and abundant food.

"The tumours are developed only on the back of the animal just above the kidneys, that is, in the place which cannot be properly protected by the goat with its horns, mouth or feet. The skin thus attacked loses from one-third to two-thirds of its value, not only because it is perforated (sometimes with as many as 100 to 200 holes), but also because it gets thinner. Skins when severely attacked are only good for the manufacture of glue. But the infested animal also diminishes greatly in value, because it loses flesh, and cannot readily endure the vicissitudes of outdoor life in Cyprus.

"The evil can be prevented by rubbing the back of the animal in due time with a cloth or sponge moistened with petroleum, or with a solution of extract of boiled laurel leaves."

THE MEASUREMENT AND CONTROL OF ATMOSPHERIC HUMIDITY IN RELATION TO ENTOMOLOGICAL PROBLEMS.

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1. Introduction.

It is a matter of general agreement that atmospheric humidity is often of great importance in limiting the times or places at which insects are abundant. But though one may collect facts which suggest that a particular degree of dryness or dampness favours some stage of an insect, it is not easy to devise experiments which will give unassailable facts. Some of us feel that the precise study of water relations and water balance may lead to greatly increased knowledge of the living insect, and therefore to results of economic value; and it is certain that a fuller understanding of these matters is delayed because few know the methods appropriate for measuring and controlling humidity.

The purpose of the present paper is to make known a number of practical methods, which might be of service to a worker even in a remote country. As this is my objective, I shall include material which is already well known to physicists, and as our concern is with the conditions in the places where insects are actually living, I have given particular attention to unorthodox devices which can be used in small spaces and which are portable; among the great variety of methods, I have endeavoured to show what is good and bad in each. Those who may use the paper are far from libraries and collections of tabulated facts. I have, therefore, put into graphical form a good deal that is available in meteorological or physical tables. I have omitted types of apparatus which are standard in meteorology. For them and for useful notes on how to use and expose them, the reader may be referred to the "Meteorological Observer's Handbook"; this should be studied by everyone who uses these instruments in the field. I have also omitted descriptions of large apparatus, the purpose of which is to control temperature and humidity in greenhouses and such places; some of these may be found described in Shelford's recent book. Stoughton's cabinets are excluded for a similar reason; his account of them is readily accessible. A full discussion of the physical problems which lie behind hygrometry is given by Bongards.

A part of the biologist's difficulty is that there are several distinct scales by which water vapour in the atmosphere may be measured; very few biologists have any comprehension of them, and our ignorance has led some of us into gross errors, though the physical principles are not difficult to grasp. It is common knowledge that a space can contain much more water vapour at a high temperature than at a low one. The line A–B in fig. 1 gives the amount of water vapour which a space will hold when it is saturated at various temperatures. In the figure in question, the amounts have been shown as vapour pressures in millimetres of mercury; but the curve would be the same if it expressed grams of water per litre of air, or tons of water per cubic mile. In any case, it expresses an *absolute humidity*. But if the air is not saturated, we may still use vapour pressure as a convenient measure of the amount of moisture in it. For instance, a particular sample of air at 20° C,

might be found to have a vapour pressure of 8·75 mm. of mercury, which is half the quantity of water required to saturate the air at that temperature. For many purposes it would be more convenient to say that such air was half-saturated, or that it had a *relative humidity* of 50 per cent.; this is the notation generally used in meteorology. It is extremely important to observe the distinction between the absolute and relative scales. A glance at fig. 1 will show that you cannot convert a relative humidity of 50 per cent. into a vapour pressure value unless you know the

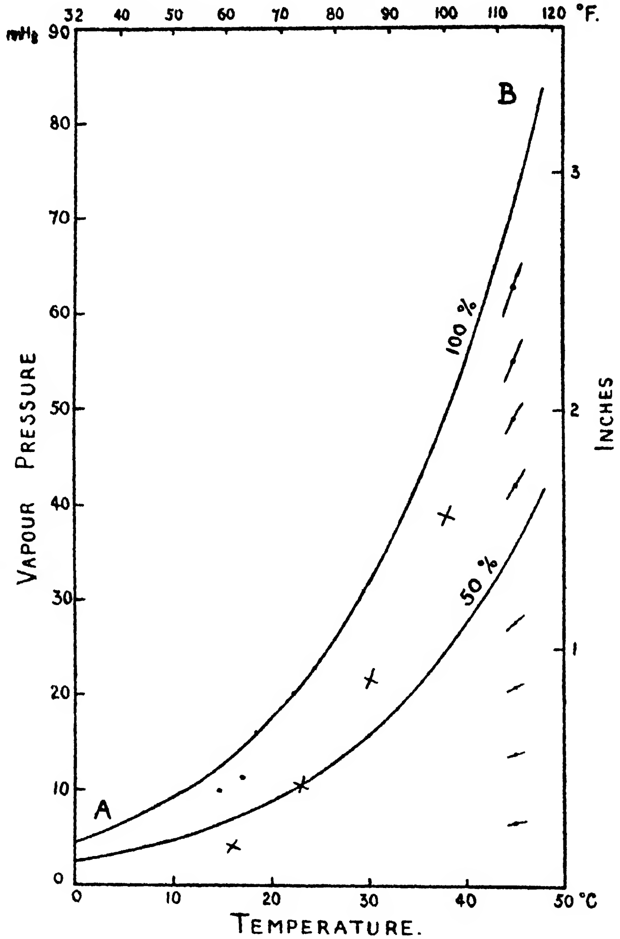

Fig. 1. Curve giving the saturation vapour pressures for water over a range of temperatures. The line for 50 per cent. humidity is drawn, and other relative humidities indicated. The graph may be used for the conversion of relative humidities, vapour pressures and saturation deficiencies from one notation to another. The crosses are all at saturation deficiencies of 10 mm.

temperature; the vapour pressure of 8·75 mm. only corresponds to 50 per cent. saturation at one temperature. For the two scales—the absolute and the relative—are not simply related to one another in the way that the temperature scales of Fahrenheit and Centigrade are. There is a third measure of humidity, generally referred to as *saturation deficiency*. Air at 29° C. is saturated (that is to say it has a 100 per cent. relative humidity) if its pressure of water vapour is 30 mm. of mercury.

If, therefore, it had a vapour pressure of 20 mm. of mercury at the same temperature, its relative humidity would be 66 per cent.; but it would be equally possible to say that it had a saturation deficiency of 10 mm. of mercury. A study of fig. 1 will show that such a saturation deficiency corresponds to different values of relative humidity at each temperature. A number of points, marked as crosses on the graph, all have a saturation deficiency of 10 mm.

From the physical point of view, none of these three notations is better or worse than another. In studying the environment of a particular insect, it may be easier to use a hair hygrometer, which gives its result as a relative humidity; or it may be easier to use some other method, which gives a result in terms of absolute humidity. But there is no difficulty in converting one's readings from one scale to another, provided always that the temperature is known. For most purposes the conversion may be done directly from fig. 1, particularly if it is drawn out on a larger scale and the lines for each 10 per cent. of relative humidity added to it. Fig. 2 sets out similar information in a different way; it may be used for the conversion of a certain relative humidity, at a known temperature, to a saturation deficiency. The use to which figs. 1

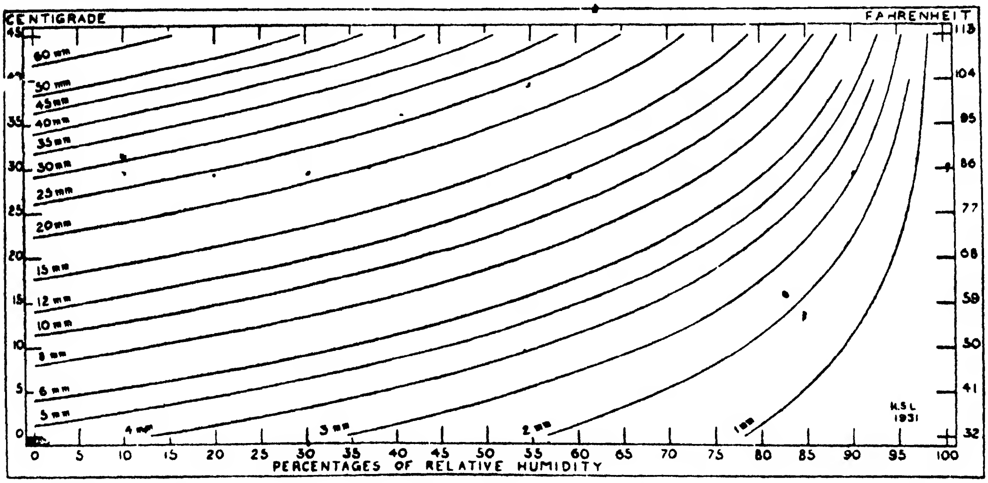

Fig. 2 Graph giving the saturation deficiency, in millimetres of mercury, which correspond to certain values of relative humidity, at the same temperature.

or 2 may be put is shown by the following example. Many years ago Brooks showed that epidemics of plague may start, and increase, over a wide range of temperature provided the saturation deficiency is 0·3 inches (8·5 mm.) of mercury, or less. Fawcett has recently published data about the prevalence of *Xenopsylla cheopis* and other fleas in Hong Kong, and the relation of this to cases of plague in man and rat, and to mean temperature, rainfall and mean relative humidity. We want to test his figures against Brooks' suggestion. One requires a pencil, pair of dividers and ruler (or celluloid set square). Taking Fawcett's tables, one puts a pencil dot on fig. 1, corresponding to each of his monthly values (dots have been inserted, corresponding to Fawcett's figures for January, temperature 61·6° F., humidity 82 per cent.; February, 58·7° F. and 82 per cent.). If this is done, it will be found that in every month the saturation deficiency is under 0·3 inches. This tends to confirm Brooks' generalisation, for plague may occur in Hong Kong in every month.

The measurement of temperature is outside our present scope, though it is essential to a study of the problems of humidity. But the worker will remember that there is a great variety of possible thermometers—resistance thermometers, thermocouples, mercury-in-steel recorders and many others. With one or other of these

it is possible not only to read, but also to record, temperature, even in places that are rather inaccessible or minute. There is, therefore, no excuse for accepting a meteorologist's measurements, obtained in a white painted screen, and assuming that they bear any direct relation to the conditions in which the insect is living. It is well to point out also that the mean temperature of a position cannot be got by halving the sum of the maximum and minimum temperatures; nothing short of a continuous record is really satisfactory. It should also be stated that the precise control of temperature in the laboratory is easy if gas or electricity is available, and not impossible with an oil lamp. Even in remote places, approximate control can be got with a hay box, or a large water bath, or in a cellar. No proper study of humidity can be made without this control.

Our concern at the moment is with measurement and control of humidity, and not with the problems of water balance in an insect. Provided that the distinction between the different scales of humidity is observed, and that the temperature is recorded, we may leave it to the insect physiologist to discover which scale may be appropriate for his purpose. But until the matter has been better investigated, it is not possible to make controlled experiments on the effect of humidity on insects. Let us take, for example, the work of Jones on the duration of the egg stage in *Cimex*. He studied it at various temperatures from 15° to 33° C. and always at a relative humidity of 75 per cent. Many people would say, though the author himself did not fall into this error, that he worked at "various temperatures and the same humidity." But this is erroneous; as the relative humidity was constant, the vapour pressure and the saturation deficiency were different at each of his temperatures, and as we know so little of the forces which determine the loss of water from an insect's egg, we cannot say whether one or two factors were varied in his experiments. At present the indications are that saturation deficiency is the best measure for our purpose, as it is for measuring the loss of water from a leaf or from a warm-blooded animal (Buxton, 1931).

2. Methods of Measurement.

The entomologist needs apparatus which is portable, and if possible strong and simple, but our problems are so varied that no one apparatus will meet them; very often we require something which is small; it is generally inadmissible to ventilate the apparatus, because this will bring air from elsewhere to the precise place which we are studying. Let us add that our standard is high; we cannot be content with inaccurate methods. From among the following, a method will be found appropriate to most of our needs. But, so far as I know, we cannot yet measure humidity at a surface, for instance, where an Aphid lives and feeds.

Dry and Wet Bulb Thermometers.

The theory underlying this instrument is that two similar thermometers are exposed side by side, the bulb of one being covered with wet muslin. Evaporation cools this bulb, and the difference between the temperature recorded by the two instruments ("depression of wet bulb") can be used as a measure of humidity, subject to certain provisos. The most important of these is that air must pass over the surface of the wet bulb at a velocity of at least 5 miles an hour; if the speed is greater than this it is immaterial. Rapid movement of the air over the bulb is most easily obtained by whirling the wet and dry bulb thermometers and reading them several times until a constant result is obtained. The readings may then be reduced by means of Assmann tables, which give vapour pressures and relative humidities. In fig. 3, I have shown graphically the relation between the thermometer readings and the relative humidity of the air; owing to the kindness of the Meteorological Office I have been able to use data calculated from the Assmann formula at

temperatures higher than those which occur in the published tables. The evaporation of water from the wet bulb and therefore the amount of cooling for any particular degree of atmospheric humidity, is affected by barometric pressure; the Assmann tables from which fig. 3 is made are correct at a barometric pressure of 755 mm. of mercury. For most purposes the correction for pressure is very small, and we can probably afford to neglect it. But if one is working at such an altitude as 3,000 feet, it is important to allow for the low barometric pressure, and this may perhaps most easily be done by using the tables of the Indian Meteorological Service (Simpson). These tables are calculated from a formula which is not identical with the Assmann formula, but the differences are very slight, except for high temperatures, combined with low relative humidities.

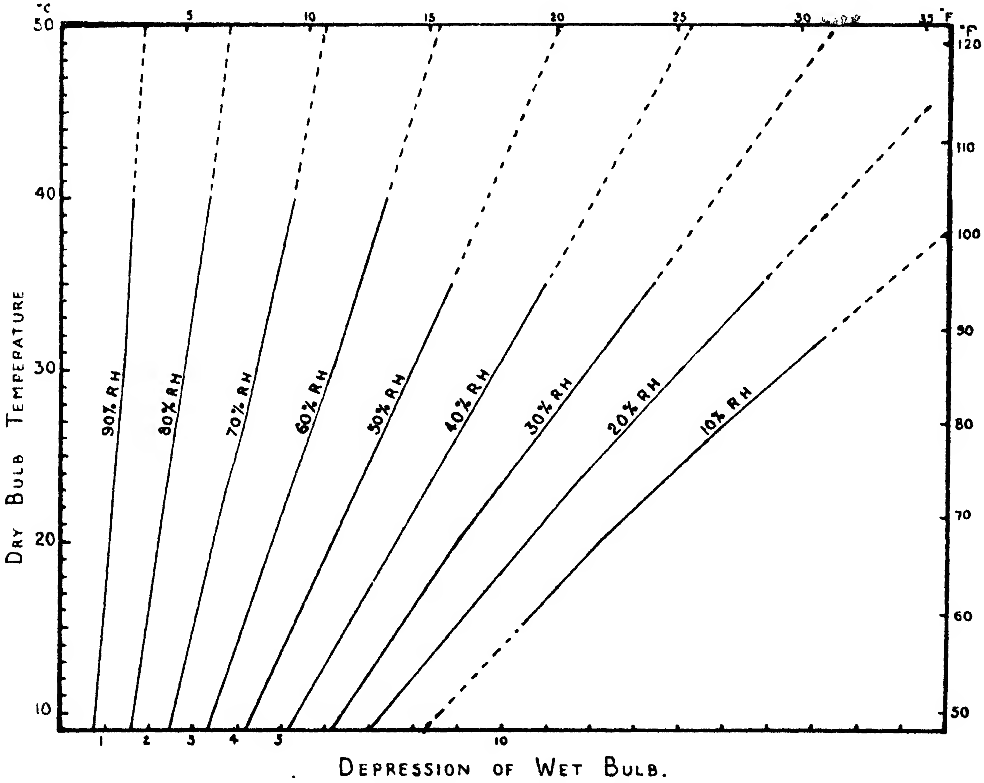

Fig. 3. Graph from which the relative humidity may be obtained from readings of dry and wet bulb thermometers (Assmann formula). The dotted lines relate to conditions that are not included in the printed Assmann tables.

For our purposes, the best form in which to use the wet and dry bulb thermometers is the whirling hygrometer. The apparatus may be used in a cave or forest, because it is simple and compact. In using it in the field, it is important to remember that the water should be distilled, and that it should be at or near to shade temperature at the time it is used. The objection to the use of any form of wet bulb thermometer is that it is unsuitable in small environments where the amount of water evaporated from it will be sufficient to alter the humidity of the air. It is also unsuitable in places where ventilation cannot be obtained. One would not, for instance, be justified in using the wet bulb in the middle of a bush, because if it were ventilated

by a fan or otherwise, air from the outside would continually be drawn over it. I may, perhaps, be permitted to say that a recent paper by Mayne describes the use of a wet bulb thermometer under conditions for which it is not suitable. He experimented on the effects of temperature and humidity upon mosquitoes which he kept in incubators. His method of measuring the humidity was to read a wet bulb thermometer within the incubator; the objections are that evaporating water within the incubator must have raised the humidity, and that he provided no means of ventilating the thermometer.

Hygroscopic Substances.

The majority of organic substances absorb water from a moist atmosphere and take up an amount which is constant for any particular relative humidity, irrespective of temperature. As these substances absorb water they become larger and heavier, and these properties may be used in devising hygroscopes. The substance most commonly used is hair, and alterations in its length are transmitted to a finger on to

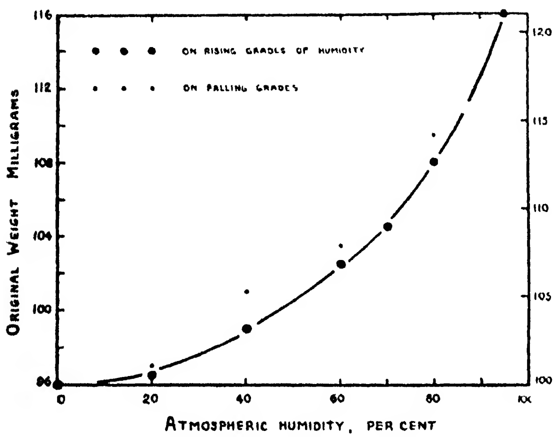

Fig. 4. Curve of weight of sample of hair at different relative humidities The line joins the values when the sample was transferred to rising humidities The small dots give the values on falling humidities

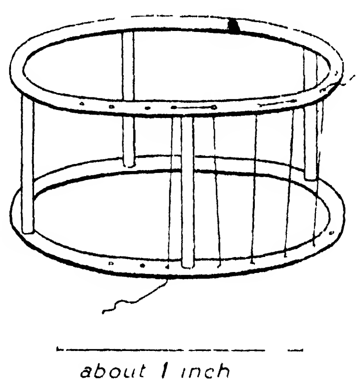

Fig. 5. Small hair hygrometer suitable for the determination of relative humidity by weighing.

a dial, or a pen on a chart. A number of excellent types of apparatus are well known and widely used; there are particular types which can be inserted through the side of a box or incubator, so that the conditions inside may be read without opening it. There are also instruments in which the finger moving round the dial makes and breaks electric contacts; with these it is possible to stop a fan blowing over a surface of water or sulphuric acid when the humidity falls below or rises above some predetermined figure. In this way the humidity may be kept constant in a cage or room. The recording type (hygrograph) is useful, particularly because so few methods of hygrometry produce a written record. Most of the ordinary hair hygrometers are rather bulky, but this could be overcome if need arose. It is well to remember that hair hygrometers develop errors, particularly if they are kept at high temperature and humidity; it is the experience of most meteorologists in the tropics that the instruments are unreliable under these conditions. They also develop errors if they are exposed to extremely low humidities. If one wishes to devise a small hair hygrometer for some particular purpose, the hair must be soaked in ether to remove wax, and make it sensitive to changes in atmospheric humidity.

The hair hygrometer depends on the fact that when hair is moistened it becomes longer; the increase in length is determined by relative humidity. It is clear that one might equally well weigh the hair, and this is frequently advantageous because accurate weighing is so easy. Though good chemical balances cannot be carried about, torsion balances are frequently used in the field for other purposes and are accurate. Moreover, a fraction of a gram of hair or some other organic material can be calibrated in atmospheres of various humidities and then placed in some place of which the humidity is unknown. It can then be removed and weighed, giving a direct measure of the relative humidity of the environment in which it has been placed. Fig. 4 shows the relation between the weight of a sample of human hair, and the relative humidity of the atmosphere in which it was kept. The facts were obtained with the little apparatus shown in fig. 5. It consists of 0·2 gms. of hair wound on an aluminium frame weighing about two gms. The hair is threaded through the holes, all round the periphery, as the sketch shows; more hair is then put on, round and round, in such a way that no considerable thickness of hair exists at any point. The whole apparatus drops into a weighing bottle, and is normally weighed in this, so that it cannot gain or lose weight while it is on the balance. We have constructed a similar but smaller apparatus, in which about 150 mg. of hair is wound on a frame of aluminium wire weighing 300 mg. In using such an apparatus, two difficulties may be encountered. Many hygroscopic substances are very slow in coming into equilibrium with the moisture in the atmosphere. Human hair is one of the quickest, partly because its diameter is small and its surface, therefore, great. The apparatus shown in fig. 5 comes into equilibrium with the atmosphere in less than five minutes. In using any hygrometer of this type, one must decide to work either on rising, or else on falling, grades of humidity, otherwise small errors will result. This is illustrated in fig. 4, in which a distinction is made between weights obtained on the up and the down grades of humidity. Wilson & Fuwa have published a large collection of facts and graphs on the relation between various organic and inorganic substances and the relative humidity of the air. Most of these substances show their greatest weight increment at the moist end of the scale; in this point they resemble hair (fig. 4). But some substances, for instance activated charcoal, show a greater weight increment in the lower part of the humidity scale. It might be possible to choose an appropriate substance for investigating a particular problem.

Hygrometry by weighing has been seldom practised, partly because it is always a special method; for one must calibrate a particular sample of a suitable substance. The advantage of the method is that the instrument is small; it might well be used for studying the humidity beneath a floor, where rats and plague fleas were breeding. The same method could be used to investigate the environment in the middle of a mass of some stored product which was being devoured by insects. Suppose that some beetle were breeding in a particular bale of tobacco, and that it was thought that its presence there was due to an unusually high proportion of moisture in the tobacco. It should be easy to remove a sample of leaf from the middle of the bale and weigh it. The sample could then be exposed in desiccators to various humidities and weighed after each exposure. From these figures it would be easy to deduce, not only the water content of the tobacco, but also the humidity of the air in the middle of the bale.

Dew Point.

The theory underlying the use of the dew point as a means of determining the amount of moisture in the air may be understood from fig. 1. Let us suppose that we are dealing with air at 30° C. and an unknown humidity, and that we cool it until it deposits dew on a silvered surface. We observe that when the temperature of the surface has fallen to 16° C. the first trace of dew is deposited. The air must now be saturated, otherwise it could not begin to deposit dew; but a space saturated with water vapour at 16° C. has a vapour pressure of 13·6 mm. of mercury. Now we have not added to the water in the original sample of air or removed any water

from it, so that the vapour pressure is unchanged. Therefore the original air at 30° C. had a vapour pressure of 13·6 mm.; but saturated air at 30° C. is known to have a vapour pressure of 31·7 mm.; therefore the air was originally $\frac{13 \cdot 6}{31 \cdot 7}$ saturated, *i.e.*, it had a relative humidity of 43 per cent. If we had wished to know the saturation deficiency from the same figures, it would have been the difference between the two vapour pressures, that is to say, 18·1 mm. of mercury.

In practice, the determination of the dew point has many advantages, for the apparatus is small and easy to carry, and the only accessory required is a bottle of ether, or, if work at temperatures much above 30° C. is contemplated, a bottle of

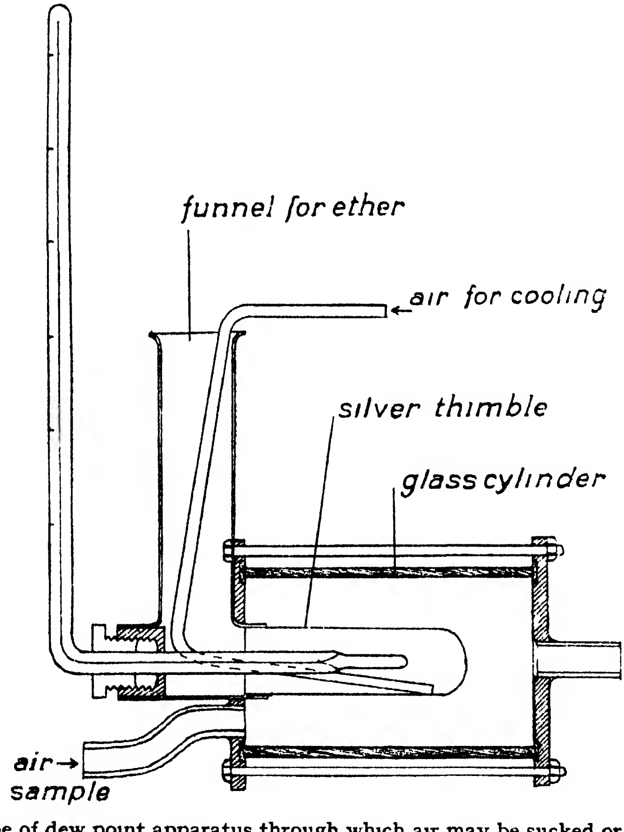

Fig. 6. Type of dew point apparatus through which air may be sucked or blown from a distant position The apparatus is water-tight and may be submerged in a bath

acetone. Dew point apparatuses can be put anywhere. They do not generally necessitate ventilation or removal of a sample of air, and they do not add any water vapour to the atmosphere which is being studied. All these points are to the good, and it is clear that the biologist must learn to use the dew point apparatus and to adapt it to his special needs. Griffiths has described a number of ingenious ways for reading the dew point at a distance with the aid of mirrors and telescopes. I have no experience of them; it would be well to remember that one might borrow apparatus designed by surgeons for illuminating and observing various cavities and orifices of the human body. With one of these, it should be quite easy to read the dew point in the middle of a heap of dead leaves without disturbing them. Fig. 6 shows a dew

point apparatus made for me by Messrs. Negretti and Zambra. The silvered surface is enclosed in a watertight cavity through which air may be blown or sucked. I frequently use this appliance in a tank of water, maintained at a certain temperature, in which I am studying the combined effects of temperature and humidity upon insects.

Chemical Hygrometers.

The general theory of chemical hygrometry is that the water vapour contained in a given volume of air is absorbed by some powerful hygroscopic substance (calcium

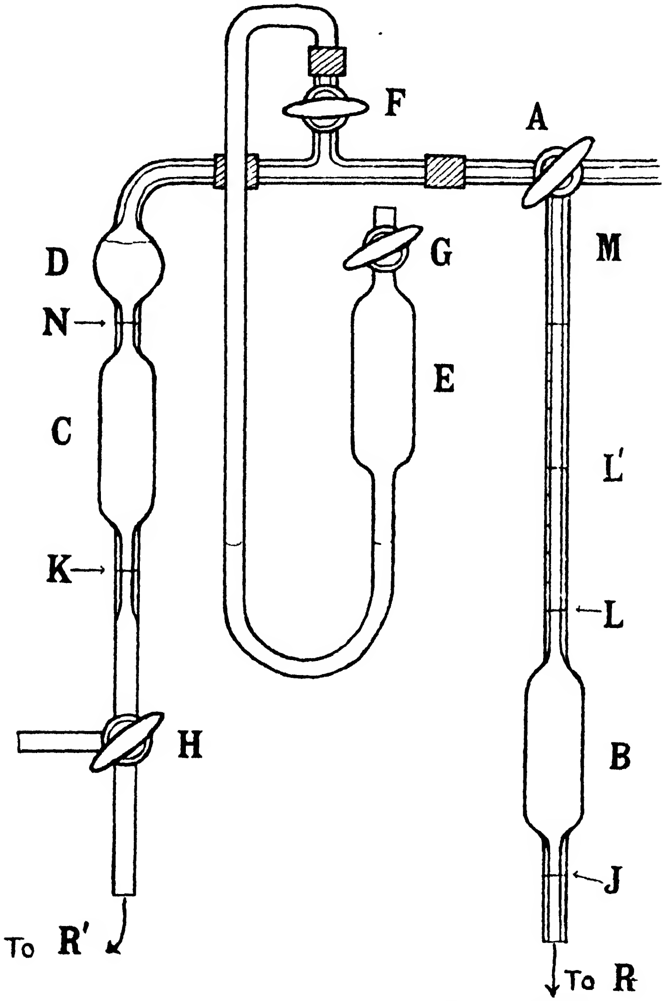

Fig. 7. Chemical hygrometer described in the text.

chloride or sulphuric acid). There are several ways of applying the method, but only one is suitable for our purposes ; a small volume of air is sucked into a closed apparatus over mercury ; the water vapour in the sample is absorbed with sulphuric acid, and the reduction of the volume of air gives a measure of its humidity. The apparatus works on the absolute scale, because the volume of water vapour in the air is determined by the ratio of its vapour pressure to the barometric pressure at the moment. To

take an example: if the temperature of the air is 35° C. and it is saturated, the vapour pressure of water will be 42 mm. of mercury (fig. 1). If the barometer is normal (760 mm.)* at the time the observation is taken, then the volume occupied by the water vapour will be $\frac{42}{760}=\frac{1}{19}$ of the total volume. It will be realised that the volume of water vapour is generally a smaller fraction than this, because the temperature at which one works is frequently much below 35° C. and the air may or may not be saturated. But even when the proportion is much less, it is possible to measure the reduction of volume when the water vapour is absorbed by the acid, and to do so with great accuracy. The apparatus was developed by Rideal and Hanna, and my colleague Mr. K. Mellanby has recently introduced several improvements. The following description of the apparatus and notes on the method of using it have been drawn up by him.

The apparatus (fig. 7) consists essentially of three bulbs, B, C and E. B and C are connected above and below to 2 mm. glass tubing. There are marks on the tubing (J L, K N), and the volumes of B and C measured between these marks are precisely equal. In our apparatus the volumes are about 10 cc. E is of the same size as B and C, but it is not necessary that it should be precisely so. D is a small bulb of about 5 cc. capacity. It will be seen from fig. 7 that much of the apparatus is constructed of wide capillary tubing of about 2 mm. diameter; this is indicated by double lines. This reduces the amount of dead space outside bulbs B and C. When the apparatus is used, the volume of water vapour absorbed will be measured on the capillary L M; its bore and length must therefore be related to the volume of B. In the example quoted above, the volume of water vapour was 1/19th of the whole. The volume of the capillary must, therefore, be a little more than 1/19th of that of bulb B, and its diameter should be such that the graduations extend over nearly the whole length of L M. There are four taps in the apparatus, of which A and H are three-way and G and F two-way. A and F are made on 2 mm. tubing. The others are ordinary taps on wider tubing. The apparatus is completed by two mercury reservoirs connected by pressure tubing, as shown schematically at R and R.′ When the apparatus is used, B and C are filled with mercury by the reservoirs, and D is partly filled with concentrated sulphuric acid; this may be introduced through tap H when the level of the mercury has been lowered. The manometer may contain anilin; as will be seen from fig. 7, it opens into the upper side of the tube AD. To use the apparatus, tap A is opened so as to put B and C in communication with the outside air. The mercury in C is then adjusted precisely to point N. F and G are now opened so that the anilin is level in the two limbs of the manometer, after which these two taps are closed. The reservoir R may be raised till the mercury fills the whole tube L M A; moreover a further length of capillary may be attached beyond A, through which air can be aspirated from some such position as beneath the floor. In that case, this further length of capillary can be filled with mercury by raising R. In this way air is completely expelled from the apparatus, before the sample is taken. R is then lowered, and the sample of air is brought into B. Or alternatively R may be raised or lowered two or three times to ensure that B will be filled with air derived from the outside and not from the space between L and A. The level of mercury is brought precisely to J. A is then turned so that B and C can communicate with one another, but not with the outside air.

At this moment we have a certain volume of air in B and we know that it is at atmospheric pressure, whatever that may be, because it has only just been shut off from the atmosphere by the turning of A. R is raised and R′ is lowered so that the sample

* For most purposes, working near sea-level, the actual barometric pressure need not be read or allowed for. But if the instrument is used much above sea-level, it must be calibrated accordingly.

of air passes over into bulb C. This should be repeated two or three times to ensure that all the water vapour in the air is absorbed by the sulphuric acid ; so far as possible one should avoid compressing or expanding the air in passing it to and fro ; this is in order to avoid possible leaks from the taps. The level of the mercury, which has been driven out of C, is now brought precisely to K. F is then opened, and it will be found that the anilin in the two limbs of the manometer is not precisely level; owing to the absorption of water from the air, the sample of air is now at a little less than atmospheric pressure. It must be compressed by raising R, until the manometer shows that the sample is at atmospheric pressure. This will be accomplished by bringing the level of mercury from L to some point such as L′. The volume of mercury between L and L′ is exactly equal to the volume of water vapour which has been extracted from the air. Had we been dealing with air which was dry before it entered the apparatus, the mercury would not have risen above L, because the volume of the air would not have been reduced by passing it over the sulphuric acid. The greater the vapour pressure of water in the original sample of air, the greater the rise from L to L′.

The instrument may be calibrated in one of two ways. L M carries a linear scale, which may be arranged by fixing a piece of graph paper behind it. The apparatus should then be filled with air which is saturated with water at room temperature, by drawing the air from a vessel full of pumice and distilled water. If this is done, a number of points on the scale can be determined which correspond to saturation vapour pressures at various room temperatures. Other points may be determined by filling the apparatus with air at known temperature and relative humidity, drawing it from vessels containing pumice and appropriate dilutions of sulphuric acid. As a second method, the apparatus may be calibrated arithmetically, the volume of B and the diameter of L M being accurately known.*

The advantages of this type of hygrometer are that a very small sample of air (say 5 cc.) can be taken, so that no artificial ventilation is created in the position which is being studied. The instrument is more accurate than any of the others described. The method would be suitable for the study of atmospheric humidity in a small cavity in a wall in which sandflies (*Phlebotomus*) might be breeding, and Mr. Mellanby has used it for measuring the humidity between the shirt and the body. One disadvantage of the apparatus is that as it is made of glass, mercury and strong sulphuric acid ; it is fragile and disagreeable if broken. It would become unreliable if different parts were exposed to different temperatures. I should suppose that if it were to be used in a hot wind, or where it was exposed to radiation, it would be necessary to protect the glass parts in a tank of water, or at least to enclose them totally in a box of wood and glass, as figured by Rideal and Hanna.

3. Methods of Control of Humidity.

The three methods described below all impart a particular relative humidity to air ; with most of them this remains constant over wide ranges of temperature. I shall describe the methods, and then some apparatus, in which they can be used.

Super-saturated Salt Solutions.

The presence of any dissolved salt in water lowers the vapour pressure over the solution. If so much salt is added to the water that some remains undissolved, it is easy to be certain that the air over the solution has a definite humidity, if the temperature is known. Moreover, even if the solution absorbs water from the atmosphere, that humidity will remain constant so long as undissolved salt is present. Special difficulties occur in the use of one or two of the salts mentioned ; for instance, lithium chloride

* Further improvements have been devised while this paper has been in the press.

gives off chlorine at 37° C. (Parker). The following list is derived from Spencer, and gives the relative humidity over super-saturated salts, at 20° C.:—$LiClH_2O$, 15%; $KC_2H_3O_2$, 20%; $CaCl_26H_2O$, 32%; CrO_3, 35%; Zn $(NO_3)_26H_2O$, 42%; KNO_2, 45%; KCNS, 47 %; $NaHSO_4H_2O$, 52%; $NaBr2H_2O$, 58%; $Mg(C_2H_3O_2)_24H_2O$, 65%; $NaClO_3$, 75%; $H_2C_2O_42H_2O$, 76%; NH_4Cl, 79%*; $(NH_4)_2SO_4$, 81%*; KBr, 84%; K_2CrO_4, 88%; K_2HPO_4, 92%; $NH_4H_2PO_4$, 93%*; $CaSO_45H_2O$, 98%. In the case of many of these salts, the relative humidity remains

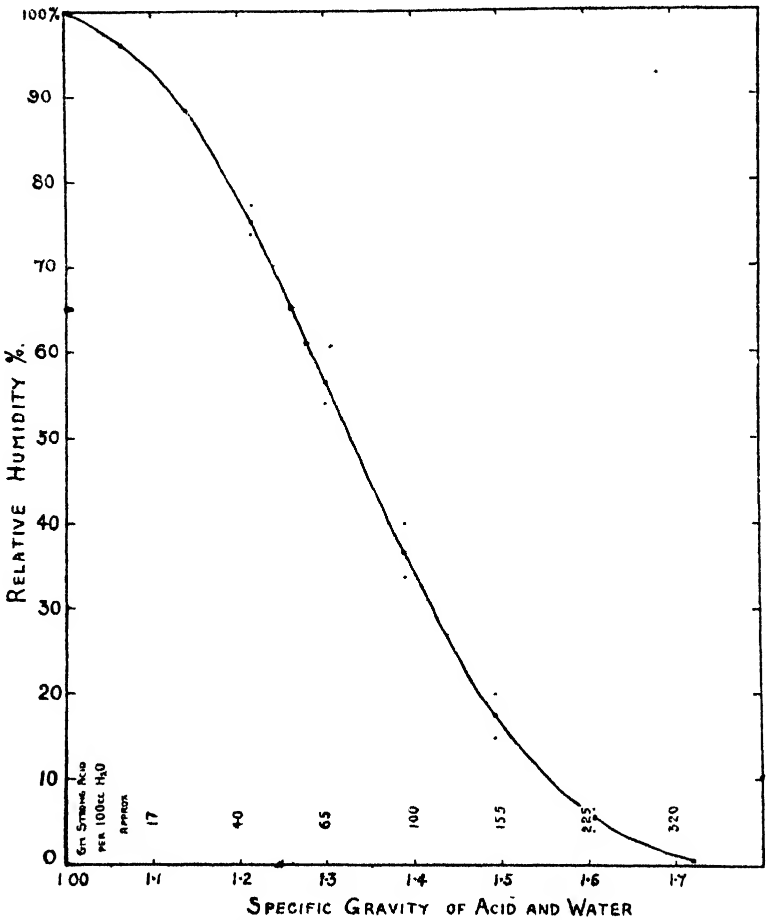

Fig. 8. Curve relating the specific gravity of mixtures of sulphuric acid and water to the relative humidity of the air over the mixture. The curve is correct at 20° C.; the dotted positions above and below the curve give values at 50° and 0° C., respectively.

constant, within a fraction of 1%, over a wide range of temperature (say from 10° to 30° C.); these salts are marked with an asterisk. But it must not be presumed that this is always so; with certain salts, the relative humidity rises, with others it falls, with rising temperature. If it is necessary, it would be easy to determine the humidity for a given salt and temperature. One could expose a small weighing hygrometer in a desiccator over the salt, or determine the dew point in a current of air which had bubbled through the salt at the desired temperature.

Mixtures of Sulphuric Acid and Water.

The disadvantages of the super-saturated solutions of salts is that they give a limited number of relative humidities, and we frequently want a particular value which is not obtainable by their use. One might, for instance, wish to carry out experiments at two temperatures, 20° and 30° C., and a saturation deficiency of 10 mm. of mercury. In this case, one would reduce everything to the relative notation, because the solutions give particular relative humidities. The saturation vapour pressure at 20° C. is 17·5 mm. (fig. 1). An atmosphere with a saturation deficiency of 10 mm. will therefore have a vapour pressure of $17{\cdot}5-10=7{\cdot}5$ mm.; that is to say it will have a relative humidity of $\frac{7{\cdot}5}{17{\cdot}5}=43\%$. By a similar line of reasoning, an atmosphere of 30° C. with a saturation deficiency of 10 mm. will have a relative humidity of 68 per cent. Now using super-saturated salts we might be unable to obtain precisely these relative humidities. We therefore turn to some substance which gives a complete range of relative humidities, and the most convenient is sulphuric acid mixed with water. The curve in fig. 8 gives the relation between the relative humidity of the atmosphere and the specific gravity of the mixture of acid and water, pure water giving a relative humidity of 100 per cent. and pure acid a relative humidity of 0 per cent. It is derived from Wilson. In using this curve, it is important to observe that the figures at the bottom of the chart give approximate numbers of grams (not cc.) of strong acid per 100 cc. of water. When the mixture of acid has been made and has become cool, its gravity must be tested with a hydrometer before bringing it into use. The acid should be pure, preferably of the "analytical reagent" grade, otherwise one cannot be sure that no fumes are given off from it.* It will be seen from the graph that the correction which should be applied even at temperatures of 0° or 50° C. is very little. The only objection to the use of a mixture of sulphuric acid and water is that in process of time the strength of the mixture alters by absorbing water or by giving it up. Methods of guarding against this source of error are discussed below.

Aqueous Solutions of Potassium Hydroxide.

If several large insects, for instance meal-worms, are enclosed over sulphuric acid and water for several days, it is probable that the carbon dioxide which they produce will be sufficient to cause their spiracles to open widely. This may well increase their loss of water, by diffusion from inside the tracheal system, and if this occurs the experimental work might be invalidated. Carbon dioxide may also be evolved in large quantities from the food in which insects are breeding. For instance, seed or grain respires, and the rate of respiration is greatly increased if the material is damp. Dendy & Elkington found it impossible to keep insects in grain at higher humidities, because the production of CO_2 was great enough to kill the insects; they were forced to experiment with vessels not tightly closed, and their control of humidity broke down. Difficulties of this sort may be overcome by keeping the insects in a slow stream of air at the required humidity (below), but this is not always convenient. Another way of avoiding the difficulty is to dispense with sulphuric acid, and control the humidity with solutions of potash, which will absorb the carbon dioxide. So far as I know, the method has not been used in biology, but it will supersede the use of sulphuric acid where relatively large quantities of carbon dioxide are likely to be produced. The objection to its use is that the absorption of carbon dioxide turns the potassium hydroxide into potassium carbonate. Paranjpe, however, points out that this does not greatly affect the humidity of the space over the solution until

* There is a possibility that even pure sulphuric acid may be toxic to insects kept over it, though its vapour pressure is very low. We know that mealworms may be kept over it for months (Buxton, 1930), but this is not necessarily true of all insects.

a considerable proportion of carbonate has formed. In any case, if a small weighing hygrometer be kept in the desiccator, the humidity may be deduced occasionally.

The data needed for the use of potassium hydroxide will be found in fig. 9. The figure gives vapour pressures over aqueous solutions of potash, at several selected

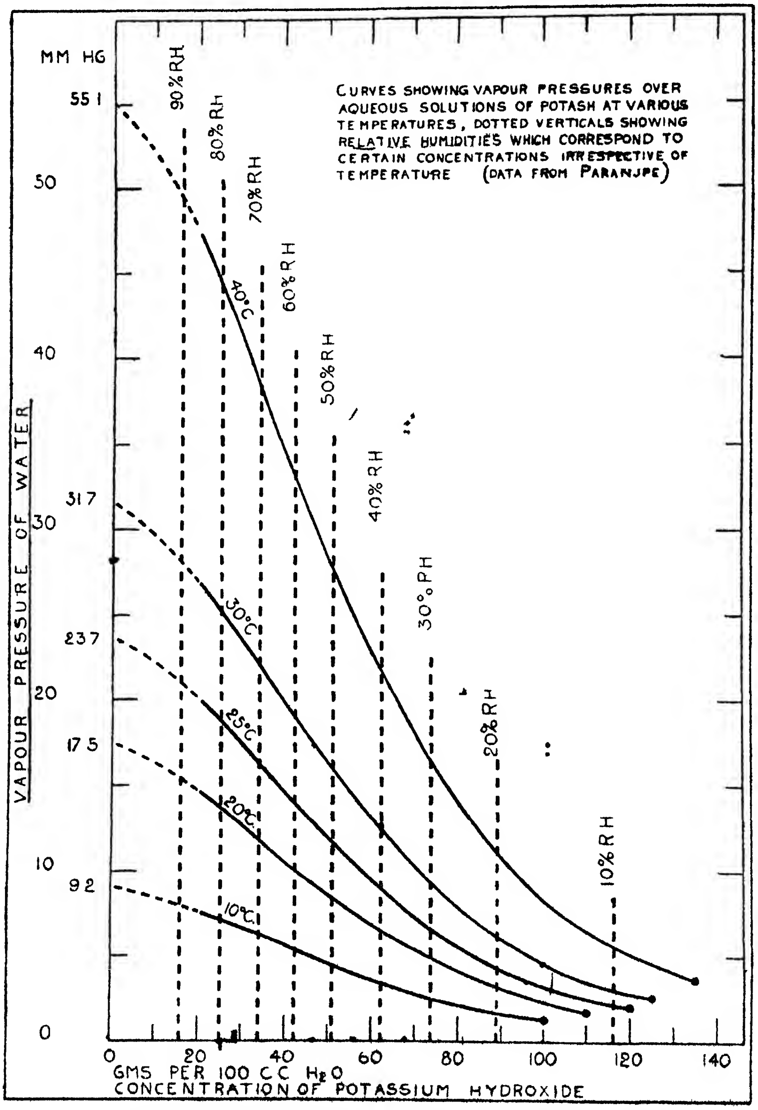

Fig 9 Curves giving the vapour pressure of water over aqueous solutions of potash at certain temperatures; measurements are not given beyond the right end of the curves, as at this point some of the potash is solid The figure also gives the relative humidity of the air over the same solutions irrespective of temperature.

temperatures; the facts are from Paranjpe's tables From them we have calculated relative humidities; it will be seen that the relative humidity is constant for any given solution, over a range of temperature. It appears from the graph that very low

relative humidities are not obtainable, but that is only true of potash *solutions*. If solid potash is used, the air over it will have a relative humidity of only 3–4 per cent.

Appropriate Apparatus.

We have then three methods, super-saturated salts, solutions of sulphuric acid, and of potash, any one of which will maintain a particular relative humidity in a closed space, even if the temperature changes. What is the most convenient apparatus in which to use these liquids? For many purposes, work may be carried out in a desiccator, or any other wide-mouthed vessel capable of being made air-tight. In such a vessel one can determine the conditions of temperature and humidity which are fatal or not to particular insects; or the duration of life under those conditions. The worker might wish to breed an insect under controlled conditions of humidity, not in order to study the effects of atmospheric moisture, but simply in order to stabilise one of the external conditions. The recent work of Brindley on *Ephestia* and *Tribolium* is an example; he wished to breed large numbers of insects under standard conditions; using a thermostat and super-saturated salt he was able to do so, two important variables being controlled in this way. If the desiccator is used for many weeks, the worker will not know whether control of humidity is still accurate; he will argue that the acid has become diluted by moisture absorbed from the insects. The accuracy of control may be tested by putting a small weighing hygrometer in the apparatus. A second question will be asked; after the desiccator has been closed, how soon is the humidity in it brought to the desired point? Mr. Mellanby has recently investigated this by aspirating samples through a hole in the top of the desiccator. He found that after the apparatus was opened, humidity in it fell from 40 to 5 per cent. in one hour, the desiccator containing pure sulphuric acid.

There are a few types of work for which desiccators are unsuitable. One might wish to maintain the insects in a slow stream of air, so as to absorb and weigh the carbon dioxide which they produced (see for instance Buxton, 1930); or one might wish to use a current of air, in order to be certain that the insect was actually exposed to the desired humidity from the beginning of the experiment. In working with desiccators one can never be certain of this, for the control of humidity is by diffusion, and is therefore not rapid. In either case, apparatus such as that described by Beattie is useful, though there are one or two improvements which have been discovered since her paper was written. The air should be blown through the system, so that if any small leaks occur, they will be outwards. If air is sucked through, as was Beattie's practice, small leaks inwards make it difficult to secure constant low humidity. The main difficulty with which one has to contend is that caused by leaks of moist air; all rubber connections must be as short as possible, and made of pressure tubing. Ground-glass joints should be used wherever it is possible to do so. I have at present in use an apparatus in which the air is brought to the required humidity by being blown through a series of three Woulfe's bottles containing pumice,* wet with an appropriate dilution of sulphuric acid. It then passes over granulated zinc, and glass wool, to arrest sulphuric acid spray, should there be any. At this point there is a Y piece, one arm of which leads to the dew point apparatus shown in fig. 6. Hygrometry may, therefore, be accurately performed on a sample of the air at any moment. A sample of air, drawn off at this point, may be bubbled through an indicator; it will be found that the air is free of sulphuric acid spray. But generally this arm of the Y piece is clamped off, and the air goes by the other limb to a container in which insects lie. From here it bubbles through liquid paraffin, which shows that it is actually coming through; it then escapes. The whole apparatus, dew point included, fits on a frame of "meccano," and stands in a tank of water,

* Many samples of pumice give off sulphur dioxide when first treated with sulphuric acid. It is well to let the apparatus run for 24 hours without insects in it, to avoid this source of trouble.

the temperature of which is heated and regulated electrically. The insects are therefore exposed to a current of air at a controlled temperature and humidity. If compressed air is not available, the apparatus described by Cannon & Grove, and commonly used for blowing air through aquaria, is excellent; it can be employed anywhere where a piped water supply exists.

There is one difficulty which seems insurmountable. In a desiccator or in a stream of air, one may study the effects of temperature and humidity on any resting stage of an insect; it is easy to expose eggs, pupae, fasting meal-worms (Buxton, 1930), or fasting ticks or bugs, which only require occasional feeds. But the method is not applicable to an insect which is feeding on a leaf, though several workers have failed to see the objection. For instance, Sweetman & Fernald put adults of Mexican Bean Beetle (*Epilachna*) in tubes with leaves of the food-plant, keeping the leaves fresh by supplying water to the stems. The tubes, which had gauze tops, were exposed in atmospheres of controlled humidity, and circulation by means of a fan was secured. Now doubtless in moist air the humidity on the surface of the leaf was close to that in the rest of the cage, but in dry air, water vapour must have been streaming away from the leaf and the insects must have been in an atmosphere much moister than that in the rest of the cage. I willingly admit that though I criticise the method, I cannot suggest an improvement; it is also clear from the results given in the paper that these authors did expose insects to several different (but unknown) degrees of humidity; it is only on the question of measurement that the method seems to me to be invalid.

But if an insect consumes " dry " food, one can keep it under controlled conditions of humidity. Making use of the fact that " dry " organic materials are hygroscopic, my colleague Miss E. K. Sikes has recently been able to measure the water content of the food of flea larvae, after it had attained equilibrium with atmospheres of various humidities. She obtained a curve not unlike that for hair (fig. 4). If, therefore, she put flea larvae in a desiccator at a certain relative humidity, she knew that their food was in equilibrium with the atmosphere, provided that the food was in a thin layer; therefore, the humidity of the atmosphere in which the larvae lived was actually controlled and the moisture content of the food was also known. The facts are set out fully in her paper. In a similar way, it will doubtless be possible to study and control the effects of atmospheric humidity on insects feeding in fur, dried fruit, tobacco or flour. It might even be possible to do the same with timber, drawing air of the required humidity through the vessels of the wood.

This paper can hardly be summarised. But it may be concluded by pointing out two of our greatest needs: we have very few types of hygrometer which make a record over a period of time; no apparatus is known to me which will record the humidity of a thin layer of air, for instance that just above the surface of a leaf.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology, between 1st April and 30th June, 1931, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Mr. A. ALFIERI :—37 Parasitic Hymenoptera ; from Egypt.

Mr. W. ALLAN :—12 Tabanidae, 9 *Stomoxys*, 3 *Auchmeromyia*, 38 other Diptera, 100 Coleoptera, 7 Lepidoptera, and 10 Orthoptera ; from Northern Rhodesia.

Mr. T. J. ANDERSON, Government Entomologist :—10 Parasitic Hymenoptera, 6 Lepidoptera, and 15 Orthoptera ; from Kenya Colony.

Mr. D. J. ATKINSON :—335 Diptera and 369 Curculionidae ; from Burma.

Mr. J. BALFOUR-BROWNE :—100 Dipterous early stages, 30 Hymenopterous larvae, 11 tubes and 5 slides of Coccidae, 6 tubes and 3 slides of Aphidae, 2 tubes of Aleurodidae, and 3 other Rhynchota ; from Madeira.

Mr. E. BALLARD, Chief Plant Pathologist :—8 Diptera, 43 Parasitic Hymenoptera and cocoons ; from Egypt.

Dr. H. F. BARNES :—9 Parasitic Hymenoptera ; from Hertfordshire.

Mr. S. S. BINDRA :—1 Ichneumonid ; from the Punjab, India.

Mr. G. E. BODKIN, Government Entomologist :—314 Diptera, 183 Hymenoptera, 236 Coleoptera, 246 Lepidoptera, 109 Rhynchota, 204 Orthoptera, and 2 Odonata ; from Palestine.

Mr. H. BRITTEN, Manchester Museum :—12 Parasitic Hymenoptera ; from Hertfordshire.

Mr. J. CARROLL :—1 species of Coccidae and 3 other Rhynchota ; from Ireland.

Dr. A. CHIAROMONTE :—5 Coleoptera, 1 Moth and 2 larvae ; from Eritrea.

CHIEF ENTOMOLOGIST, PRETORIA :—6 Parasitic Hymenoptera and 6 Coleoptera ; from South Africa.

CHIEF VETERINARY OFFICER, BURAO :—6 Orthoptera ; from British Somaliland.

Mr. L. D. CLEARE, Junr., Government Entomologist : — 35 Siphonaptera, 26 Diptera, 3 Parasitic Hymenoptera, 9 other Hymenoptera, 54 Coleoptera, 2 species of Aphidae, 500 other Rhynchota, 11 Orthoptera, and 2 Shells ; from British Guiana.

Prof. T. D. A. COCKERELL :—12 Diptera, 2 Parasitic Hymenoptera, 81 other Hymenoptera, 33 Coleoptera, 32 Lepidoptera, 2 species of Coccidae, 12 other Rhynchota, and 15 Millipedes ; from various localities.

Mr. G. H. CORBETT, Government Entomologist :—48 Diptera and 30 larvae, 283 Parasitic Hymenoptera, 5 other Hymenoptera, 25 Coleoptera, 70 Lepidoptera, 140 Isoptera, 22 Thysanoptera, 6 species of Coccidae, 1 species of Aphidae, 26 other Rhynchota, 7 Orthoptera, and 200 Mites ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—8 Tabanidae, 270 other Diptera, 281 Hymenoptera, and 10 Lepidoptera ; from Kenya Colony.

Mr. A. CUTHBERTSON, Assistant Entomologist :—3 *Stomoxys*, 3 *Lyperosia*, 31 other Diptera, 3 Rhynchota, and 6 Orthoptera ; from Southern Rhodesia.

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Mr. P. R. DUPONT :—60 Diptera, 2 Chalcididae, 82 Coleoptera, and 1 species of Coccidae ; from the Seychelles.

Mr. W. H. EDWARDS, Government Entomologist :—3 Parasitic Hymenoptera and 16 Coleoptera ; from Jamaica.

Mr. J. C. M. GARDNER, Systematic Entomologist :—293 Parasitic Hymenoptera and 5 species of Coccidae ; from the United Provinces, India.

Mr. F. D. GOLDING, Government Entomologist :—14 Diptera, 34 Coleoptera, 3 Rhynchota, and 9 Orthoptera ; from Southern Nigeria.

Miss L. F. GRAHAM :—7 Parasitic Hymenoptera ; from Australia.

Prof. G. GRANDI :—1 Braconid ; from Italy.

Dr. W. J. HALL :—20 Tachinidae ; from Southern Rhodesia.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—23 Hymenoptera, 104 Lepidoptera, 205 Orthoptera, 3 Plecoptera, and a tube of Parasitic Worms ; from Uganda.

Mr. C. S. M. HOPKIRK :—1 tube of Mites ; from New Zealand.

Mr. G. V. HUDSON :—75 Coleoptera and 15 Rhynchota ; from New Zealand.

Mr. M. A. HUSAIN, Government Entomologist :—19 Diptera, 8 Parasitic Hymenoptera, 12 other Hymenoptera, 69 Coleoptera, 12 Lepidoptera, 34 Rhynchota, 5 Orthoptera, 8 Dermaptera, and 3 Planipennia ; from the Punjab, India.

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Mr. F. P. JEPSON, Assistant Entomologist :—800 Isoptera ; from Ceylon.

Mr. J. T. KENNEDY :—22 Coleoptera, 20 Thysanoptera, and 76 Rhychota ; from Uganda.

Mr. C. B. R. KING :—6 Diptera and 45 Mites ; from Ceylon.

Mr. M. A. LIEFTINCK :—1 Ichneumonid and 2 pupae and 2 cocoons ; from Java.

Dr. J. W. SCOTT MACFIE :—300 Culicidae and 950 early stages, 5 Tabanid larvae, 26 *Glossina*, 6 Nycteribiidae, 273 other Diptera, and 10 early stages, 61 Dipterous slide preparations, 45 Coleoptera, 90 Cimicidae, 1 species of Coccidae, 20 Mallophaga, and 10 Mites ; from West Africa.

Mr. T. L. McLELLAND :—21 Parasitic Hymenoptera and 65 Coleoptera ; from Kenya Colony.

Dr. D. MILLER, Cawthron Institute :—5 Coleoptera ; from New Zealand.

Mr. J. C. v. d. MEER MOHR :—70 Parasitic Hymenoptera ; from Sumatra.

Mr. J. MUGGERIDGE, Government Entomologist :—380 Coleoptera, 50 Thysanoptera, 2 species of Aphidae, and 66 Mites ; from New Zealand.

MUSÉE DU CONGO BELGE, TERVUEREN :—2 Parasitic Hymenoptera, 4 Lepidoptera, and 7 Orthoptera ; from the Belgian Congo.

Dr. J. G. MYERS :—6 Diptera, 172 Parasitic Hymenoptera, 54 Coleoptera, 17 Lepidoptera, 7 Rhynchota, and 22 Orthoptera ; from Tropical America.

Dr. T. A. M. NASH :—23 Parasitic Hymenoptera ; from Tanganyika Territory.

Mr. E. H. OGIER :—1 species of Coccidae ; from Guernsey.

Dr. A. OGLOBLIN :—3 Curculionidae ; from the Argentine.

Prof. G. PAOLI :—1 Moth ; from Italian Somaliland.

Mr. F. H. POLLEN :—6 Siphonaptera ; from Hampshire.

Mr. R. PUSSARD :—36 Parasitic Hymenoptera ; from France.

Dr. A. REYNE :—2 Diptera, 2 Parasitic Hymenoptera, 2 Curculionidae, 2 Lepidoptera, and 5 Orthoptera ; from the Dutch East Indies.

RHODESIA MUSEUM, BULAWAYO :—65 Coleoptera ; from Southern Rhodesia.

Mr. A. H. RITCHIE, Government Entomologist :—22 Coleoptera, 2 Lepidoptera, 20 Thysanoptera, 2 species of Coccidae, and 76 other Rhynchota ; from Tanganyika Territory.

ROYAL BOTANIC GARDENS, KEW :—8 Coleoptera ; from the Seychelles.

Capt. A. H. ST. CLAIR, Locust Research Officer :—29 Orthoptera and 10 Mites ; from Kenya Colony.

Mr. R. N. SAVORY :—25 Dipterous puparia, 3 Lepidoptera and 105 early stages ; from Dutch Guiana.

Mr. H. B. SMART :—153 Hymenoptera and 8 early stages, and a Bee's nest ; from British Honduras.

SOUTH AUSTRALIAN MUSEUM, ADELAIDE :—345 Curculionidae ; from Australasia.

Dr. H. H. STOREY :—1 species of Aleurodidae and 25 other Rhynchota ; from Tanganyika Territory.

Mr. SUREYA BEY :—1 Bird and 6 Mammal skins ; from Turkey.

Mr. C. B. SYMES, Medical Entomologist :—4,000 Culicid larvae ; from Kenya Colony.

Mr. E. L. TAYLOR :—2 Parasitic Hymenoptera ; from Surrey.

Mr. J. S. TAYLOR :—24 Rhynchota ; from South Africa.

Mr. T. H. C. TAYLOR :—8 Culicidae, 33 Parasitic Hymenoptera and 4 cocoons, and 10 Coleoptera ; from Fiji.

Dr. P. TCHORBADJIEV :—52 Parasitic Hymenoptera, 4 other Hymenoptera, 54 Coleoptera, and 19 Orthoptera ; from Bulgaria.

Mr. F. W. URICH :—32 Coleoptera and 4 larvae, and 6 Lepidoptera ; from Trinidad.

Mr. R. VEITCH, Chief Entomologist :—2 Jassidae ; from Queensland.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—74 Parasitic Hymenoptera, 36 other Hymenoptera, 227 Coleoptera, 54 Lepidoptera, 161 Rhynchota, and 30 Odonata ; from the Sudan.

Mr. F. X. WILLIAMS :—27 Diptera ; from Honolulu.

THE ASH CONTENT OF INSECTS.

By E. B. Uvarov,

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Introductory.

In the recent summary of the literature on insect nutrition and metabolism by B. P. Uvarov,[1] it was pointed out that the ash analyses hitherto carried out were apt to contain considerable inaccuracies and errors due to the small size of insects and the consequent difficulty of obtaining sufficient quantity of material. Another probable source of error was the fact that analyses were generally carried out on whole insects (the only partial analyses of any importance being those of insect blood), thus including the whole of the digestive tract, containing substances which were not utilised by the insect at all.

In the present work an attempt has been made to overcome the first difficulty by the use of colorimetric methods, requiring only small amounts of material. The second source of error presents an extremely difficult problem which has not been solved with any degree of success, although an attempt was made to investigate the extent of error involved.

The physiological significance of the metals copper, iron and manganese, has long been recognised as an interesting problem. Special attention was given to the estimation of these elements in the insects examined.

Historical Survey.

Those elements which are well known to occur universally throughout the animal kingdom—such as potassium, sodium, magnesium, phosphorus, silicon and calcium—have nearly always been reported by investigators working in this field. In addition, the following elements have been reported :—Copper, zinc, chlorine, aluminium, arsenic, sulphur, manganese, iron, boron, titanium, lead, iodine, fluorine and nickel. Some of these appear to be doubtful, having been noted by some workers and not by others ; it seems quite likely that the extremely small amounts of some of these elements which have been occasionally recorded may have been swallowed by the insect with its food and may not have been a constituent part of the organism at all.

The first ash analysis in the literature is the work of Hornung & Bley,[2] who analysed the chitin of beetles, detecting calcium, magnesium and iron. Giunti[3] was the first worker to draw attention to the occurrence of copper in animals, including the insects *Anomala vitis* and *Blatta orientalis*. Peligot[4] analysed the ash of mulberry leaves, silkworms and their excreta, but the only metals found by him were iron, calcium, magnesium and potassium. Packard[5] detected a trace of copper in locust ash. Aronssohn[6] made a study of the mineral composition of the bee, detecting (in addition to the commoner elements) arsenic, copper, manganese, zinc, aluminium and fluorine. According to McIndoo & Demuth,[7] however, the presence of arsenic in bees may be attributed to the spraying of fruit trees with arsenic compounds. Haber[8] analysed the blood of the cockroach spectroscopically, detecting aluminium, potassium, titanium, copper and zinc, all qualitatively only. Muttkowski[9] made a special study of the presence of copper in insects, analysing 34 species in all, and found considerable amounts of copper in every case. He suggested that the respiratory pigment of the blood may be haemocyanin, but unfortunately no direct test for this pigment is known. Bertrand & Macheboeuf[10] found no definite evidence of nickel in silkworms.

The foregoing references cover most of the fundamental work on the subject that has been published. There are numerous other papers containing records of analyses of various species of insects, but these are all very fragmentary and

inconsistent. Our present knowledge is therefore far from complete, and it is not yet possible to establish any connection between differences in ash content in different species. This is not surprising when it is remembered that most of the work has been carried out with some other purpose in view. In the present work a systematic analysis of certain species of insect has been made with the definite object of attempting to show whether any such connection between the ash content of different species does exist.

Nature of Experiments and Species tested.

The work may be divided into three main parts: small-scale analysis of museum specimens with digestive tracts removed; small-scale analysis of specimens with digestive tracts intact; and large-scale analysis of the ash of a large number of locusts. This last gives values which provide a check on the small-scale results and also renders possible the detection and estimation of elements whose percentage is very low.

The small-scale analyses were made chiefly by colorimetric methods. In the majority of cases several samples or batches of the same material were taken, and the results given represent the mean of these. Wherever possible, the reagents used were of "A.R." (Analytical Reagent) purity. "Blanks" were performed on the reagents used to ensure that they did not contain traces of impurities. So far as was possible, each estimation was carried out at least in duplicate, and in the case of the colorimetric estimations at least four readings were taken in each case. The accuracy of each colorimetric method was verified by experimenting with solutions of the respective elements.

The following insects were analysed :—

ORTHOPTERA, ACRIDIDAE.

1. *Schistocerca gregaria*, Forsk. Museum specimens, intestines removed.
2. ,, ,, ,, Sexually immature (red) adults, entire specimens.
3. ,, ,, ,, Sexually mature (yellow) adults, entire specimens.
4. As 3, but on a larger scale.
5. *Acanthacris ruficornis*, F. Museum specimens, intestines removed.

HEMIPTERA, PENTATOMIDAE.

6. *Agonoscelis versicolor*, F. Entire specimens.

Small-Scale Analysis.

1. *Total Ash and Silica Estimations.*

The insects were washed with water, then with alcohol and ether, and dried for several days *in vacuo* over sulphuric acid. Samples containing a known number of insects were weighed out into a platinum basin. The basin was then heated to 500–600° C. in an electric muffle furnace for several hours, until most of the carbon had been burnt off. On cooling, hydrochloric acid was added (1 part of water to 1 part acid), the ash crushed thoroughly, evaporated to dryness on steam, and ignited to constant weight. The total ash content was thus estimated.

Silica was estimated in the usual way by rendering it insoluble by repeated evaporation with hydrochloric acid, filtering off and heating with hydrofluoric acid. The residue from this was fused with potassium bisulphate, extracted with water and made up to 50 cc. The filtrate from the silica was made up to 100 cc.

2. *Copper Estimations.*

Copper was estimated colorimetrically, using a 0·1 per cent. solution of sodium diethyl dithiocarbamate.[11] Standard copper solutions of various strengths were prepared by weighing out copper sulphate and diluting to the required strength. The unknown solution was treated with ammonia, filtered, and 10 cc. of the reagent added. The colour obtained was compared by means of a Klett colorimeter with a standard treated in the same way.

3. *Iron Estimations.*

Iron was estimated colorimetrically by two methods, namely the thiocyanate and the ferrocyanide methods. The thiocyanate colour with iron is the more sensitive reaction, but the colour is not directly proportional to the amount of iron present, owing to certain ionisation factors. The less sensitive ferrocyanide method therefore gives more accurate results if no corrections are applied.

4. *Manganese Estimations.*

These were carried out colorimetrically by the periodate method. The solution was boiled with 5 cc. of strong sulphuric acid till all the hydrochloric acid had been driven off, then a little potassium periodate was added and the solution boiled. The violet colour obtained was compared with the colour of a similarly treated standard solution, prepared by weighing out manganese chloride.

Large-Scale Analysis.

The insects were first charred in a large porcelain basin. The mass was then crushed and ignited in a large platinum basin. The ash was ignited to constant weight and finely ground. About 2 grams was weighed out into a platinum crucible and fused with sodium carbonate. The melt was extracted with hydrochloric acid and silica was estimated as in the small-scale estimations. The filtrate was acidified and boiled and saturated with hydrogen sulphide. The precipitate was filtered off, and to the filtrate a known volume of standard ferric chloride was added to combine with excess phosphate. Perhydrol was added to oxidise any ferrous iron, and the solution was boiled. Ammonia was then added till the solution was faintly alkaline. The precipitate was filtered off and washed. It was then redissolved in hydrochloric acid and precipitated with ammonia, the two filtrates being collected together. The precipitate was ignited and weighed as "mixed oxides."

Calcium, manganese and *nickel* were estimated in the combined filtrates in the usual way by oxalate, phosphate and dimethylglyoxime respectively. The mixed oxides precipitate was treated by the usual group table method adopted in the presence of phosphates to eliminate iron and phosphate, and the filtrate from this was analysed as previously.

Alkalies were estimated by the method of J. L. Smith.[12]

Barium and *manganese* were estimated by treating a portion of the ash with sulphuric and hydrofluoric acid repeatedly, taking up with water and filtering, The filtrate was examined for manganese colorimetrically, and the residue for barium gravimetrically.

Iron and *titanium* were estimated in the same sample of ash. Iron was estimated volumetrically by reducing with hydrogen sulphide and titrating with potassium permanganate. Titanium was estimated colorimetrically by hydrogen peroxide.

Phosphate was estimated by precipitating as magnesium pyrophosphate.

Copper was estimated colorimetrically as above.

Sulphate was estimated as barium sulphate.

Chloride was weighed as silver chloride.

Moisture and *unburnt carbon* were estimated in the ordinary way.

Summary of Results.

Only the mean results for several batches in most cases are given.

Results expressed as percentage of total ash.

	Locusts, large scale.	Yellow locusts.	Red locusts.	Locusts (mus. sp.)	Acanthacris.	Agonoscelis.
Total ash		3·75	3·65	3·98	3·01	2·97
Silica ...	11·9	6·27	14·7	15·2	6·33	16·25
Copper ...	0·13	0·29	0·26	0·17	0·43	0·20
Fe_2O_3 ...	2·06	1·27	1·73	4·57	1·92	5·45
Manganese	0·16	doubtful	doubtful	traces	traces	0·47
Na_2O ...	6·2					
K_2O ...	18·2					
CaO ...	6·2					
MgO ...	4·9					
TiO_2 ...	0·16					
Ni ...	0·009					
P_2O_5 ...	32·4					
SO_3 ...	2·56					
Cl ...	0·40					
Carbon ...	2·4					
Moisture ...	0·54					

Conclusion and Summary.

In the case of silica, there appears to be a definite variation of SiO_2 content with different species. The difference between yellow locusts (6·27 per cent.) and red locusts (14·7 per cent.) is especially marked. It may be attributed to the fact that red locusts are actively feeding, sexually immature adults, and in consequence they consume large amounts of food with a high silica content. The fact that museum specimens of yellow locusts contain a higher percentage of silica than intact yellow specimens indicates that the majority of the silica is not concentrated in the digestive tract. The same appears to apply to the iron content. Copper was found in appreciable quantities in all the insects examined, but no definite conclusion can be drawn from the numerical results, as the variation from batch to batch was too great. The results for manganese are not satisfactory, as in several cases negative evidence was obtained. This is inconsistent with the work of Vinogradov,[13] who obtained conclusive evidence of manganese in insects. In the case of *Agonoscelis*, however, the manganese content was found to be extraordinarily high (0·47 per cent.), suggesting that it may play a definite physiological part. The presence of a respiratory pigment, *pinnaglobin*, containing manganese, has been shown in the tropical mussel,[14] but there is as yet no evidence for the presence of this pigment in the insect world.

It is impossible, however, to draw any such conclusions from ash analysis results of entire insects only, and systematic analyses of the blood of numerous species will be necessary to establish the presence of the metals iron, copper and manganese, in their respiratory pigments.

Definite evidence of nickel (in almost negligible amounts) was shown by the large-scale analysis, but apart from this no element was detected which had not been previously reported.

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In conclusion, the thanks of the writer are due to Mr. B. P. Uvarov for suggesting the work, to Dr. Janet W. Brown for advice and help on microchemical analysis, and to Mr. H. B. Johnston, Sudan, and M. Regnier, Morocco, for the specimens used in analyses.

THE LARVA AND PUPA OF *URANOTAENIA ORNATA*, THEO.

By Sophia L. M. Summers Connal, M.B.E., M.A., D.Sc.

The Medical Research Institute, Lagos, Nigeria.

The larvae of *Uranotaenia ornata*, Theo., are commonly found in pineapple plants in the neighbourhood of Lagos, Nigeria, and invariably in company with *Harpagomyia* larvae.

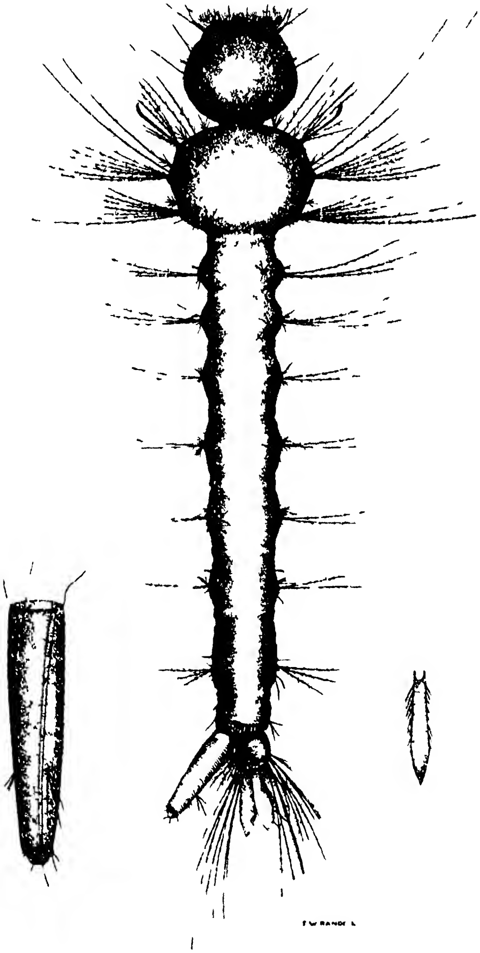

Fig. 1. Larva of *Uranotaenia ornata*, Theo

The full-grown larva (fig. 1) is about 5·5 mm. in length and greyish in colour. Head broad, almost the breadth of the thorax. Antennae short and stumpy, with a single hair at the middle and one or two at the tip. The mid-frontal hairs are represented by two not very stout bristles, and the posterior by two long fine hairs. The thorax is ornamented with a pair of long bristles from the dorsal surface and bunches

of bristles at the side. At the anterior end there is a distinctive feature, namely a pair of short, very stout bristles which are feathered towards the tip. The abdominal segments have short, stellate, stubby hairs as well as long paired hairs. The comb on the last segment consists of a row of 12 long, pointed, notched teeth. The siphon is about five times as long as broad and has a plume of three hairs at two-thirds of the length. The pecten is peculiar, consisting of fringed semi-circles running up almost to the plume, and at first difficult to discern. When the siphon is mounted so as to bring the pecten to the edge, the semi-circles appear as small notches.

The pupa (fig. 2), in life, can easily be picked out by the sharply contrasting dark brown of the posterior part of the thorax and first four segments of the abdomen against the light yellow of the remainder. There is a pair of dorsal tufts on the first

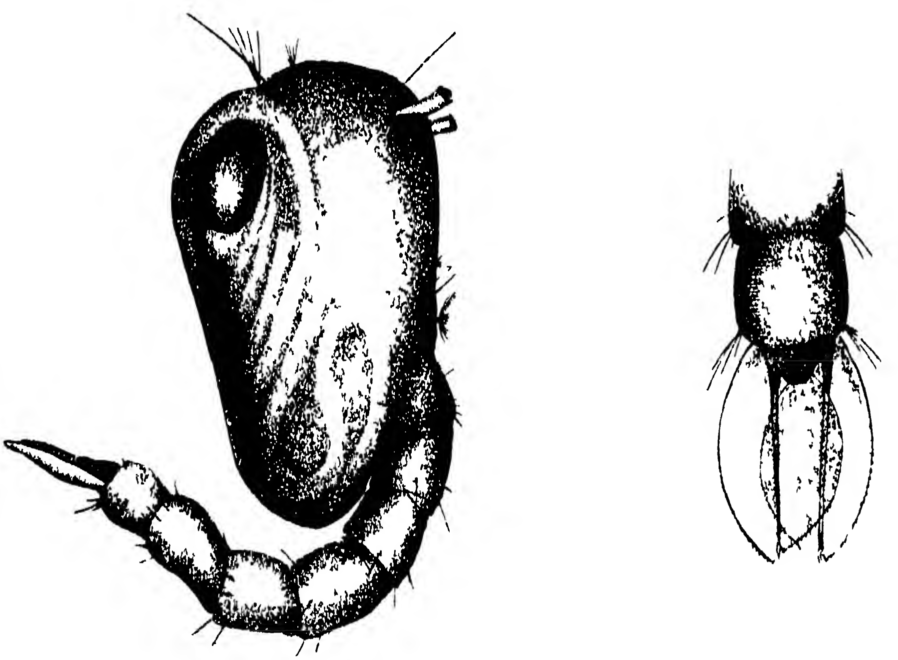

Fig 2 Pupa of *Uranotaenia ornata*, Theo

segment of the abdomen, but very few setae on the other segments. The paddles are notched and the mid-rib of each paddle divides it asymmetrically, the broader half being on the inside. Each paddle has a small terminal seta. The paddles have been figured previously by Bacot (Report of the Entomological Investigations undertaken for the Yellow Fever (West Africa) Commission, pp. 140–146).

ON THE OVIPOSITION OF *TOMASPIS SACCHARINA*, DIST. (RHYNCH., CERCOP.), AN INSECT PEST OF SUGAR-CANE IN TRINIDAD.

By Alan Pickles, B.Sc., A.I.C.T.A., F.E.S.
Entomologist, Trinidad Froghopper Investigation.

Introduction.

Tomaspis saccharina, Dist., is a Cercopid bug which infests the cane-fields of Trinidad in vast numbers during the wet months of the year. Corresponding with the successive generations, there are three, and sometimes four flights or broods of adults, each of which causes severe damage to the cane. This damage, or "froghopper blight," as it is locally called, is a result of the feeding activities of the adult on the foliage, and is characterised by a progressive discoloration of the leaves, leading to death of the affected leaf and, in severe cases, to the death of the cane. In either event, growth of the plant is more or less severely checked and the adverse effect on yield is usually of a very significant nature.

Almost since the commencement of anti-froghopper measures, it has been recognised that some localities are relatively immune from blight, while neighbouring fields are severely blighted each year (12, p. 27). A particularly evident case of this has long been recognised in the Naparima district, where two markedly contrasted soil types occur, often side by side. One of these, a red clay soil, supports canes which suffer serious blighting every year, while canes grown on the other, a black calcareous marl, invariably escape serious damage. Hardy (1, p. 202), working from this basis, has established a positive correlation between freedom from blight and alkalinity of soil in the cane-growing areas of the Colony generally. By measurements of the calcium status of "good" and of "bad" soils, Turner has substantiated this relationship (10).

In spite of such a correlation in the field, Hardy has shown that if a fairly heavy population of froghoppers be caged over canes growing on good and bad soils respectively, blight is produced equally on both types (2, pp. 386–387); subsequent observations (5) have confirmed this, and it therefore seems possible that the explanation of the relative immunity of certain areas is not to be found in the physiological relations of the cane plant with the soil.

The eggs of the froghopper are laid in the dead leaves of the cane plant while still adhering to the stem, and also in the soil surrounding the stool (11, p. 20). Hardy attempted to establish experimentally a relationship between the number of eggs laid and the characters of the substratum, but the conditions were highly artificial and the results are inconclusive (3).

An attempt was made by the present writer to investigate such a possible relationship in the field, by comparing the egg populations in different soil types, around canes of comparable ages. As the most marked distinctions of good and bad soil types occur in the Naparima district, this area was selected for the first studies and the results were later substantiated by further investigations in the north of the island.

Methods.

The extraction of the eggs of *Tomaspis* from soil is a matter of some difficulty. The eggs are quite small (0·75 by 0·25 mm., 13, p. 58) and to obtain them, it is necessary to search through a large bulk of soil. In order to pulverise the soil and also to reduce its bulk as much as possible, an apparatus essentially similar to that described by Morris (6) was employed (fig. 1*a*). This consists of three sieves of 30, 50

and 70 mesh to the linear inch, mounted one above the other in a suitable stand, with the coarse sieve above and the finest at the bottom, and the disintegration of the soil is effected by a stream of water. A tapered ring fits around the bottom of each sieve in order to guide the water and mud issuing from it into the sieve below. Clearance is provided between successive sieves so that the contents may be stirred by

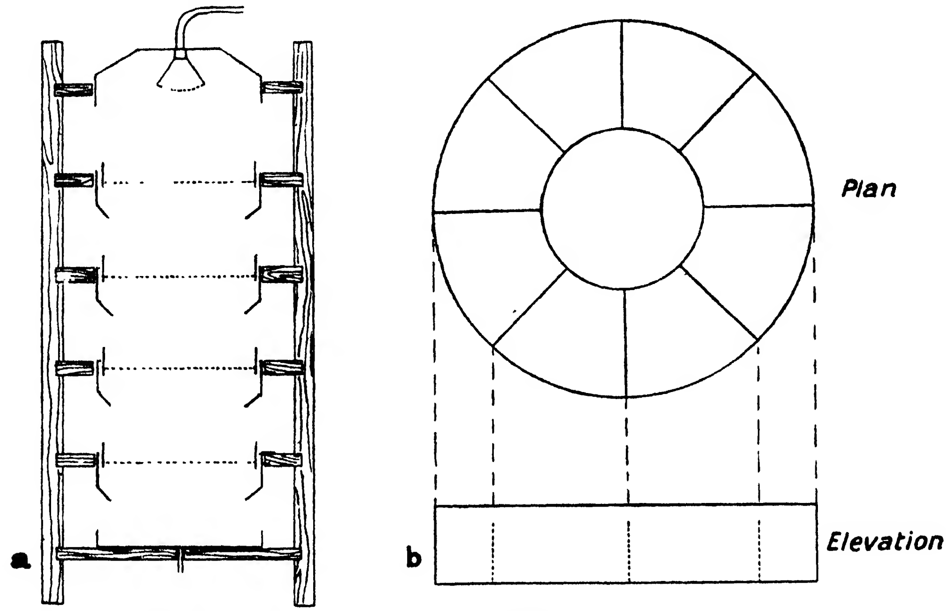

Fig. 1. Apparatus for examining froghopper eggs in soil: *a*, for explanation see p. 461; *b*, see p. 466.

hand. The soil sample to be examined is placed in the top sieve and water from a rose is sprinkled on it, with constant stirring of the sample. The stirring is maintained until only organic matter and stones remain in the sieve; the contents of the lower sieves are then stirred and the stream of water is maintained until the water issuing from the bottom sieve is perfectly clear. In this way, the clay and the finest sand particles are washed out of the sample, considerably reducing its bulk; froghopper eggs and soil particles of approximately the same size are retained in the 70-mesh sieve, the contents of which are then placed in the sun to dry and subsequently spread out in small quantities on black paper and carefully examined for eggs. Any eggs which are found are put aside and counted. The method was tested by introducing a known number of eggs into a soil sample, all of which were recovered, and results were verified by two workers checking each others' counts.

The samples were obtained by two methods. The original method was to skim off a layer of soil 6 inches wide and 1 inch deep from around the stool with a cutlass. Any soil between the stems was carefully brushed out and added to the rest of the sample. This method was employed in the experiments at the Usine Ste. Madeleine. The samples taken from Orange Grove Estate were removed in sectors, twelve to each stool, the circumference of each sector being 6 inches from the nearest cane-stalk. This modification was introduced in order to observe the regularity or otherwise of the egg distribution around the stool.

Small soil samples from laboratory cage experiments were broken by hand into a vessel of water and stirred by means of an electric stirrer prior to sieving. In the early observations at Caroni Estate, which are also of some interest here, the samples were pulverised in an iron mortar and were sieved dry (8, p. 150).

Relation between Susceptibility to Blight and Egg Content of Soils.

Soil samples were taken by the method described above from three fields on the estates of the Ste. Madeleine Sugar Company on the 24th May 1930. Two of these fields had an extremely bad reputation for blight ; of these, number 5 Harmony Hall had a typical red clay soil, while 35 Harmony Hall had a brown clay soil, which probably belongs to an alluvial series. The third field, 34 Tarouba, had a typical black marl soil and had the reputation of being always free from blight. Four stools in each field were chosen at random for sampling, and the results are shown in Table I, which is slightly modified from a table already issued in a departmental publication (9).

TABLE I.

Field	Soil type	Blight characters	Sample No.	No. of unhatched eggs	No. of hatched eggs
5 Harmony Hall	Red clay	Subject to severe blight	I	180	numerous
			II	60	numerous
			III	56	79
			IV	60	70
			Mean per stool	89	
35 Harmony Hall	Brown clay	Subject to severe blight	I	409	numerous
			II	107	—
			III	55	numerous
			IV	44	661
			Mean per stool	154	
34 Tarouba	Black Marl	Rarely, if ever blighted	I	2	—
			II	1	—
			III	4	—
			IV	0	1
			Mean per stool	1-2	

In spite of the evident insufficiency of samples and considerable stool to stool variation, there seems to be a very real difference between the egg populations of the susceptible Harmony Hall fields and the nearly immune field at Tarouba. This is in accordance with the hypothesis here put forward, that soil characters affect oviposition in soil and consequently the froghopper populations in fields on different soils, and that this difference results in variations in the degree of blighting, according to the froghopper population directly, and not to resistance of the canes as a result of growing in good soil.

In the northern part of Orange Grove Estate, there are two fields (O.G.5 and O.G.8) which, although separated only by a short distance and with soils of a closely similar type, nevertheless differ considerably in their history with regard to froghopper outbreaks. Orange Grove 5 suffers from blight each year and seems also to be one of the first fields in which froghoppers appear, while O.G.8 is seldom damaged and is only slightly affected even in the worst years. Both fields at the time of sampling were growing ratoons of B.H.10/12. The results of the egg surveys of these fields, which were sampled on 23rd August, 1930, are shown in Table II.

TABLE II.

Field No.	Sample No.	Total eggs
O.G.5. ...	c I	129
	c II	55
	c III	66
	c IV	41
	c V	44
	c VI	26
O.G.8... ...	c XIII	2
	c XIV	9
	c XV	5
	c XVI	5
	c XVII	0
	c XVIII	2

These results again suggest most markedly that the difference in the degree of blight produced in the two fields is correlated with a difference in the number of froghoppers present. In order to determine a factor which might explain the reason for the apparent avoidance of O.G.8, Professor Hardy has communicated particulars of the soil constants of the two fields, which are shown in Table III.

TABLE III*

Field	Moisture content at point of stickiness	Percentage of sand	Index of texture	Hygroscopic coefficient	Max. water-retaining capacity	Wilting coefficient	Organic matter	%N	C/N ratio	PH A	PH B
O.G.5	38·8	44·6	30	3·80	73·9	6·1	2·24	0·16	8·2	7·5	6·9
O.G.8	37·1	37·6	29	4·04	71·7	6·5	1·76	0·13	8·2	6·9	6·5

* The figures are means of values determined on A and B samples, each of which was a composite of 50 spot samples obtained from the surface inch layer of soil.

It is difficult to see from these values such a difference as would account for the preference of O.G.5 to O.G.8 by froghoppers, and there is therefore some ecological factor at work which is not yet elucidated. This matter is still receiving experimental attention.

Attention was drawn later to another field at Usine Ste. Madeleine, Cedar Hill 45, which appeared to be eminently favourable for an egg survey. This field, which is treated as a single unit for cultivation purposes, has soil of two contrasted types within its boundaries, exhibiting a sudden change from a red clay to a black marl. Canes grown on the red soil are susceptible to froghopper blight, while those on the black soil are not. Samples for investigation were taken as near to the junction as possible, eight samples from each kind of soil. Unfortunately during the year 1930 when these studies were made, the general froghopper incidence in this area was low, so that the results are not so striking as could be desired. Such as they are, however, they point to the same conclusion as that drawn from the preceding experiments. The figures obtained are shown in Table IV.

TABLE IV.

Date sampled		Sample No.	Soil type	No. of eggs
30.ix.1930	...	CUR I	Red Clay	0
,,	...	CUR II	,,	4
,,	...	CUR III	,,	6
28.xi.1930	...	CUR IV	,,	1
,,	...	CUR V	,,	2
,,	...	CUR VI	,,	1
,,	...	CUR VII	,,	1
,,	...	CUR VIII	,,	1
30.ix.1930	...	CUM I	Black Marl	0
,,	...	CUM II	,,	0
,,	...	CUM III	,,	0
28.xi.1930	...	CUM IV	,,	0
,,	...	CUM V	,,	0
,,	...	CUM VI	,,	0
,,	...	CUM VII	,,	0
,,	...	CUM VIII	,,	0

There being unmistakable indications of a correlation between freedom from blight and the number of eggs in the soil, it becomes necessary to determine the extent to which eggs are confined to the soil. Urich has opined that at the commencement of the dry season there are scarcely any eggs in the trash of the canes, the vast majority being in or on the ground ; this opinion does not appear to have been published. Corroborative evidence of this has been obtained in the course of the studies just detailed, and there is also reason to believe that throughout the year, there is an overwhelmingly large proportion laid in the soil.

The general experience during the year 1930 has been that eggs were difficult to find in the trash, but were abundant in the soil. Actual figures of the number of eggs in trash have been obtained from Orange Grove Estate, where the trash was stripped from the same stools from which soil samples were taken, and are as follows :—

TABLE V.

Stool No.	Date sampled	Eggs in trash	Eggs in soil
A I	17.vii.1930	0	37
A II		0	35
A III	(First brood eggs).	3	16
A IV		0	15
A V		1	65
A VI		0	24
B I	6.viii.1930	0	52
B II	(Second brood eggs)	0	28
B III		0	47
C I	23.viii.1930	0	129
C II	(Third brood eggs)	0	55
C III		1	66
C IV		1	41
C V		0	44
C VIII		4	26
C XIV		1	2
C XV		0	9
C XVI		0	5
C XVII		0	0
C XVIII		0	2
	Totals	11	698

Detailed counts of this nature have not yet been made elsewhere, but as stated above, there is a great probability that these figures represent the general situation. To what extent this is true of all years cannot be stated as yet, and the weather conditions during the dry season of 1930 certainly were abnormal. If these figures really represent the usual state of affairs and the great bulk of froghopper eggs are always laid in the soil, it follows that soil characters may reasonably be of paramount importance in determining froghopper distribution. The results will also have a significant bearing upon agricultural practice in regard to the disposal of trash.

Situation of the Eggs in the Soil.

In order to determine the intimacy of the relation between the eggs and the soil in which they are laid, cage experiments were conducted. A Naparima red clay soil, of 50 mesh grade, was put into the compartments of a sector tray of the type devised by Professor Hardy. This is a circular tray of galvanised iron (fig. 1, *b*), 7 inches in diameter, with a central compartment 2 inches in diameter. The space around this compartment is divided into eight sectors, with radial walls $2\frac{1}{2}$ inches long. Cane leaves standing in a bottle of water were placed in the central compartment to supply food for the insects, and the sector chambers were filled with soil. The soil was thoroughly saturated with water and then allowed to dry until it was just damp, when the tray was provided with a closely fitting gauze cylinder into which about fifty live froghoppers were introduced, and covered. After three days, when most of the insects were dead, the tray was removed and the soil blocks were dried.

On examination, a few eggs were seen to have been dropped at random on the surface of the soil. Seventeen of these were counted. The blocks were then churned with water and sieved, and the resulting soil sample was examined for eggs, 401 being recovered. This shows that normally the eggs are *inserted* in the soil and not simply scattered on the surface.

The experiment was then repeated, using hand-crushed, moist soil, over which about 200 froghoppers were caged. One sector was examined after drying, with a low power of the microscope and numerous eggs could be seen partly buried in the soil. All the eggs so visible were picked out with a needle and counted. Thirty eggs were picked off the surface and 65 were found inside the soil block.

A second block was taken and a layer of approximately $\frac{1}{16}$ inch was scraped off. This yielded 84 eggs, while the remainder of the block was found to contain only seven eggs. Finally, a third block was divided into layers of $\frac{1}{16}$ inch, $\frac{1}{4}$ inch and $\frac{1}{2}$ inch respectively, from the surface downwards. The uppermost horizon contained 141 eggs, the second contained 2 eggs, while no eggs at all were found in the third.

Gravid females also were observed while attempting to oviposite in very wet soil. The ovipositor, which is quite short (12), was seen to pierce the soil and to be withdrawn after about half a minute. This action made a short inclined tunnel in the surface of the soil, but no egg was found in this on examination. Since most of the eggs in soil cultures were completely concealed, as shown above, it seems probable that a definite attempt is made by the adult to cover over a hole in which an egg has been deposited, but this action has not yet been observed.

These results show at any rate that the egg is in intimate contact with the soil after laying, and it is reasonable to suppose that certain soils or conditions of soils are distasteful to ovipositing females and are therefore avoided, or may even render oviposition mechanically impossible. Further, this intimacy of contact of egg and soil renders soil characters of prime importance in governing the hatching of eggs already present. It is known that in air, froghopper eggs require a humidity corresponding to 90 per cent. R.H. for hatching. In soil, they will doubtless require a soil-atmosphere humidity of this order, which will depend upon weather conditions and also upon the water-supplying power of the soil.

That froghopper eggs in the field are not laid in intimate contact with the cane stumps is shown by an early experiment at Caroni Estate. An attempt was made on this estate to destroy froghopper eggs in the soil by removing cane stumps from the field after ploughing, and burning them. This procedure was expensive, and it was considered desirable to test the value of the practice (9, p. 151). Two adjoining fields were selected for study, Frederick 72 and Frederick 73, which had shown comparable froghopper incidence during the preceding wet season, as shown in Table VI. In this table, froghopper and blight incidence are marked according to the following arbitrary scale of degrees, which is the one employed by the Froghopper Investigation Committee (14) :—

Nymphs : 5=over 25 nymphs per stool ; 4=16—25 ; 3=11—15 ; 2=6—10 ; 1=0—5.

Adults : 5=over 75 adults per stool ; 4=41—75 ; 3=26—45 ; 2=11—25 ; 1=0—10.

Blight : 5=very severe, plant destroyed, no recovery ; 4=severe, dark brown streaks numerous and contiguous ; 3=fairly severe, streaks dark brown ; 2=moderate, streaks pale but conspicuous ; 1=slight, leaves yellowish.

Area affected : 5=whole field and surrounding drains and traces affected ; 4=whole field affected ; 3=three-quarters of field ; 2=one-half of field ; 1=one-quarter of field ; x=field slightly affected.

In the table, the first figure in each space indicates the incidence and the second shows the area affected.

TABLE VI.

	Frederick 72			Frederick 73		
Date	Nymphs	Adults	Blight	Nymphs	Adults	Blight
10.viii 1929	3–4	1	—	3–4	—	—
17.viii.1929	—	—	—	3–4	1–x	—
24.viii.1929	—	—	—	2–4	1–4	—
31 viii.1929	—	1–x	1–x	—	1–x	1–x
7.ix.1929	—	1–x	—	—	—	—

An average sample of the stumps from Frederick 73 was taken on the 18th April and removed to the laboratory. The soil was beaten completely off the stumps, making a sample of 20 lb. weight. This was dry-sieved and examined for eggs, only one empty shell being found. The cleaned stumps were kept moist until the end of July, but no nymphs appeared.

As a control, a strip of soil 4 inches wide and 2 inches deep was removed on the same day from around four stools in Frederick 72 and the samples were examined for eggs. The results are shown in Table VII.

TABLE VII.

Stool No.	Weight of sample	No. unhatched eggs	No. hatched eggs	Total
1	4½ lb.	8	16	24
2	5 lb.	7	16	23
3	6 lb.	10	55	65
4	7½lb.	15	12	27
Totals ...	23 lb.	40	99	139

This shows that the eggs are normally laid in the surface soil, but not in close contact with the roots of the cane.

There is thus a very complete case for the theory that the production of froghopper blight is determined by the abundance of froghoppers and not by the metabolic activity of the canes as Mumford (7) has suggested. It is admitted, however, that recovery from a blighted condition after the cessation of froghopper attacks may very probably be affected by the physiological relations of the cane, which in that event will partly govern the actual economic loss. Further, since the abundance of froghopper eggs in the soil depends on the condition and nature of the soil, soil characters are directly responsible in determining the severity of blight.

Acknowledgements.

The writer is indebted to Professor Hardy for numerous valuable suggestions and contributions during the course of these studies, and without his organisation of froghopper records, the work would have been impossible, and to Mr. C. K. Robinson, Second Officer in the Division of Entomology, who is responsible for the examination of the laboratory cultures. Thanks are also due to the managers of estates who have assisted materially by their co-operation and hospitality.

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ON AFRICAN SANDFLIES (DIPT.).

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(Plates XXII & XXIII.)

The following notes deal with a collection of sandflies from Africa sent for identification by Sir Guy Marshall, C.M.G., F.R.S., of the Imperial Institute of Entomology, by Dr. Pontes from Mozambique, by Major W. F. M. Loughnan, R.A.M.C., Mauritius, and with a number of specimens lent to Prof. Adler by the London School of Tropical Medicine. I am indebted to Prof. Adler for placing this material at my disposal.

Our knowledge of the sandflies of Africa is very incomplete. Newstead has described a number of species, and later the great majority of African sandflies have been determined as *Phlebotomus minutus* var. *africanus*, Newst., the identification having been based on the palp formula ; but it appears from more recent observations that this formula is similar in a number of different species.

In 1926 and 1927 Adler & Theodor re-described *P. minutus* and *P. africanus* and described *P. parroti*, using characters of the buccal cavity, pharynx and spermatheca.

In 1929 Adler, Theodor & Parrot described a number of new species from the Belgian Congo and re-described several old species hitherto insufficiently described.

In 1930 Sinton described an additional number of species and gave a very useful bibliography of the known records of African sandflies.

In the same year Parrot published another paper on sandflies from various localities in Africa.

Altogether there are now 20 species recorded from Africa which are fully described and 4 doubtful ones, the types of which have to be re-examined before their systematic position can be ascertained.

List of African Species of Phlebotomus.

1. *P. papatasii*, Scopoli 1786.
2. *P. perniciosus*, Newstead 1911.
3. *P. sergenti*, Parrot 1917.
4. *P. minutus*, Rondani 1843.
5. *P. babu*, Annandale 1910.
6. *P. africanus*, Newstead 1912.
7. *P. squamipleuris*, Newstead 1912.
8. *P. ingrami*, Newstead 1914.
9. *P. simillimus*, Newstead 1914.
10. *P. fallax*, Parrot 1921.
11. *P. parroti*, Adler & Theodor 1927.
12. *P. schwetzi*, Adler, Theodor & Parrot 1929.
13. *P. schoutedeni*, Adler, Theodor & Parrot 1929.
14. *P. collarti*, Adler, Theodor & Parrot 1929.
15. *P. decipiens*, sp. n.
16. *P. rodhaini*, Parrot 1930.
17. *P. freetownensis*, Sinton 1930.
18. *P. yusafi*, Sinton 1930.
19. *P. nairobiensis*, sp. n.
20. *P. langeroni*, Nitzulescu 1930.

Doubtful Species.

21. *P. duboscqui*, Neveu Lemaire 1906.
22. *P. roubaudi*, Newstead 1911.
23. *P. minutus* var. *antennatus*, Newstead 1912.
24. *P. bedfordi*, Newstead 1914.

The majority of the species from Africa belongs to the *minutus* group or " recumbent-haired " group of Newstead, characterised by the presence of a prominent armature in the buccal cavity. There are several species of the " erect-haired " group which possess very small teeth on the ventral plate of the buccal cavity, e.g. *P. argentipes* and *P. perniciosus*, but these teeth are nearly invisible in whole preparations and can be made out properly only in sections. They can therefore be omitted for systematic purposes.

The only species of the " erect-haired " group which is found everywhere in the North and North-East of Africa is *P. papatasii*. *P. sergenti* and *P. perniciosus* belong to the Mediterranean region only.

Only two species of the *minutus* group have been observed so far to bite man, *P. schwetzi* (Schwetz, 1928) and *P. babu* (Lloyd & Napier, 1930). Several records which state that " *P. minutus* var. *africanus* " bites man need confirmation and more exact identification of the sandflies concerned.

Phlebotomus squamipleuris, Newstead 1912.

P. ghesquierei, Parrot 1929.

This species (female only) was described originally from the Sudan. There were apparently no additional records of it from Africa until 1929. In 1923 Sinton recorded the species from India and described both sexes. In 1927 he added the description of the characteristic buccal armature and spermatheca.

In 1929 we received five female specimens from Mozambique, 2♀♀ collected in Lourenço Marques by Dr. Pontes (30th July 1929) and 3♀♀ collected by Mr. P. Lesne in Nova Chupanga near Chemba (9th May 1929). They all show the typical buccal armature and spermathecae of *P. squamipleuris*.

The African specimens differ from the Indian form in several details of external morphology.

P. squamipleuris var. **indicus,** nov.

The segments of the antennae are relatively shorter in the Indian form, especially the third one, but the relation $3 < 4 + 5$ is the same in both forms.

There are about 36–40 teeth in the buccal cavity in the African and about 33–36 in the Indian form (Plate XXIII, fig. 2). The pigmented area is either an elongate

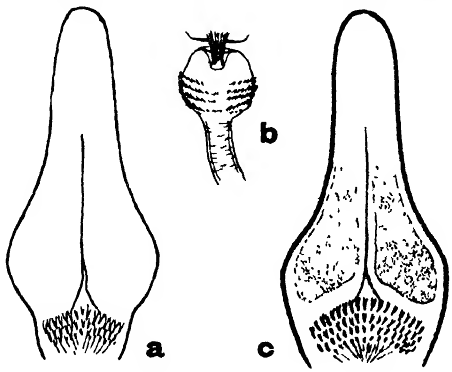

Fig. 1. *Phlebotomus squamipleuris* : *a*, pharynx of ♀ ; *b*, spermatheca. *P. squamipleuris indicus* . *c*, pharynx of ♀.

ellipse or a narrow segment of a circle with the flat side anteriorly in the Indian form. In the African form it is banana-shaped with the concave side anteriorly.

The pharynx is less chitinised in the African specimens, the teeth being less marked than in the Indian form, and shows a narrowing in its posterior part which is absent in the Indian specimens (text-fig. 1).

The wing index varies in both forms from <1 to >1, *e.g.* it was 1·3 in two African specimens and 0·87 in two others ; it was 0·87, 1, 1·1 and 1·5 in four Indian specimens. The armature of the buccal cavity and the structure of the male genitalia leave no doubt that the species belongs to the *minutus* group. The wing index α/β cannot therefore be used to sub-divide *Phlebotomus* into two groups, as suggested by Franca & Parrot (1921).

Parrot's description of *P. ghesquierei* agrees in every detail with that of *P. squamipleuris*, and this name has therefore to be considered as a synonym, as Parrot himself pointed out in a footnote in his last paper.

Phlebotomus babu, Annandale 1910.

Material examined : 8♀♀, 6♂♂ (*Major Loughnan,* Mauritius).

Phlebotomus schwetzi, Adler, Theodor & Parrot, 1929.

P. symesi, Sinton 1930 (n. syn.).

This species has been fully described in a previous publication, and the equally full description of *P. symesi* by Sinton, which is based on material from the same

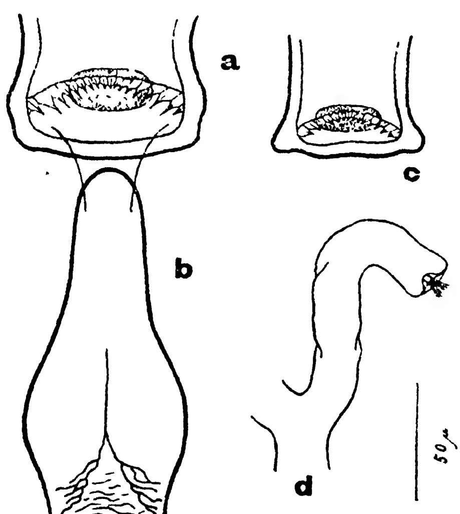

Fig. 2. *Phlebotomus schwetzi : a,* buccal cavity of ♀ ; *b,* pharynx of ♀ ; *c,* buccal cavity of ♂ ; *d,* spermatheca.

source as the material at our disposal, leaves no doubt as to the identity of the two species. The name *P. symesi* has therefore to be considered as a synonym of *P. schwetzi* (text-figs. 2 ; 3, *a*).

Material examined : 23 ♀♀, 4 ♂♂ from Mombasa, xi.1929 (*C. B. Symes*).

Phlebotomus yusafi, Sinton 1930.

This species resembles somewhat *P. schoutedeni*, from which it differs mainly in the number of teeth in the buccal cavity and in the pharynx, in which the teeth are less developed and less numerous. The inferior clasper in the male genitalia is relatively much shorter than in *P. schoutedeni* (Plate xxii, fig. 1 & text-figs. 3*b*, 4*a*, 4*b*).

Material examined : 3 ♂♂, 1 ♀, Mombasa, xi.1929 (*C. B. Symes*).

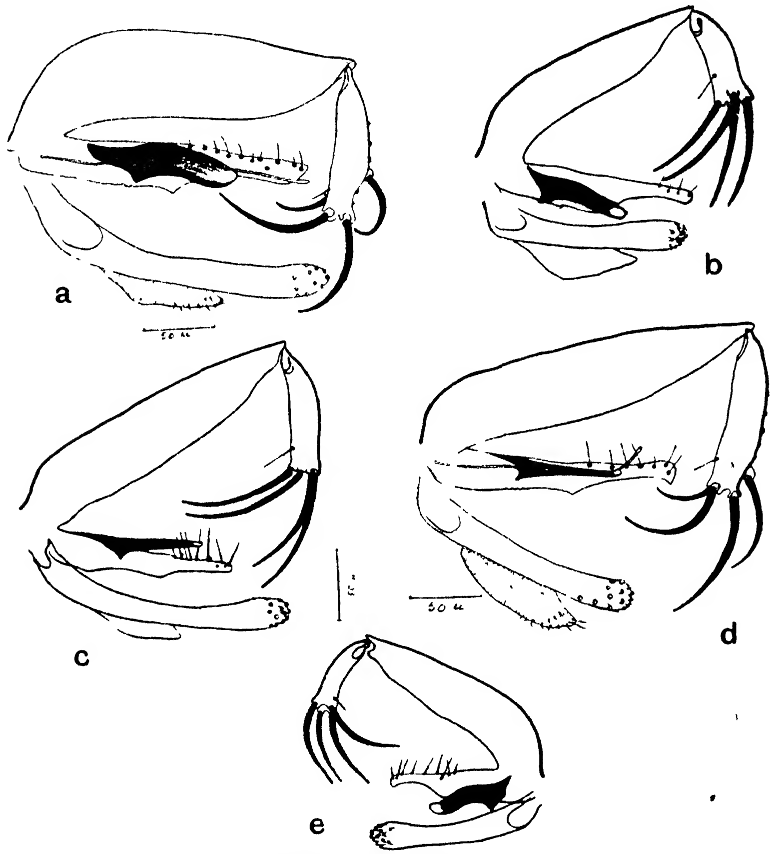

Fig. 3. Male genitalia of : (*a*) *Phlebotomus schwetzi* ; (*b*) *P. yusafi* ; (*c*) *P. simillimus* ; (*d*) *P. decipiens* ; (*e*) *P. nairobiensis*.

Phlebotomus nairobiensis, sp. n.

♀. Size : 2 mm. Palp formula : 1, 2, 3, 4, 5. Antennae : segment 3 < 4+5. Wings : length, 2 mm. ; breadth, 0·4 mm. ; index a/β=0·45—0·8.

Buccal cavity with the armature consisting of about 40 very fine pointed teeth, which are almost equal in size and shape and stand on an arc slightly concave posteriorly ; the pigmented area irregularly elliptical, the posterior margin ragged (text-fig. 4, *d*). Pharynx (Plate xxii, fig. 2) bearing a large number of very fine pointed teeth in a broad band across the posterior part, about three times as broad posteriorly as anteriorly. Spermathecae tubular but narrower than those of *P. minutus*.

♂. Size, antennae and palps as in ♀. Wings : length, 1·4—1·7 mm. ; breadth, 0·3 mm. ; index a/β=0·5—0·6.

Buccal cavity with 25–30 fine pointed teeth standing on an arc slightly concave posteriorly; median teeth slightly narrower than lateral ones; pigmented area very small, indistinct, often absent (text-fig. 4, *c*). Pharynx slender, with some fine point-like teeth in posterior portion. Genitalia with proximal segment of superior clasper 2·5 times as long as distal one; small anterior seta on distal segment very near the four terminal big spines; median appendage and penis blunt (text-fig. 3, *e*); inferior clasper longer than median appendage.

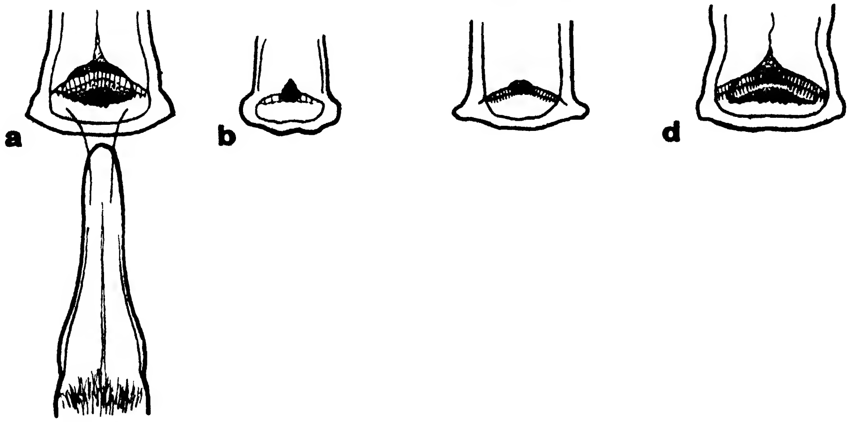

Fig. 4. *Phlebotomus yusafi* : *a*, buccal cavity and pharynx of ♀; *b*, buccal cavity of ♂. *P. nairobiensis*, buccal cavity of; *c*, male; *d*, female.

This species resembles *P. schoutedeni* very closely. The female can be easily distinguished by the greater number of teeth in the buccal cavity and by the much broader pharynx with its numerous teeth. The male is only distinguishable by the number and shape of the teeth in the buccal cavity, which are 30 in number and finely pointed in *P. nairobiensis*; 16–18 in number, broad, with short points in *P. schoutedeni*. There are no means of distinguishing the males of the two species by characters of external morphology.

Material examined: 3 ♀♀, Nairobi (*C. B. Symes*); 8 ♀♀, 8♂♂ Jinja, Uganda, May 1930; 7 ♀♀, 15 ♂♂ Jinja, Uganda, September 1930 (*E. G. Gibbins*).

Types in the Department of Parasitology, Hebrew University, Jerusalem.

Phlebotomus decipiens, sp. n.

P. simillimus, Adler, Theodor & Parrot 1929 (*nec* Newstead 1914).

In our paper on the sandflies of the Belgian Congo a species of *Phlebotomus* was described which in its external morphology closely resembled *P. simillimus*. At that time the type and cotypes of *P. simillimus*, Newstead, were not available. An examination of the cotypes in the British Museum by Prof. Adler showed that the two species were quite distinct in all characters now known to be essential. Other specimens from the London School of Tropical Medicine showed the same characters as the cotypes.

P. simillimus has recently been described as a new species by Parrot under the name of *P. brodeni*. The description leaves no doubt that *P. brodeni* is a synonym of *P. simillimus*, and the species has therefore to be sunk.

For the species from the Belgian Congo which was considered as *P. simillimus* I propose the name *P. decipiens*. A full description of this species has been given in the paper referred to (Rev. Zool. Bot. afr., xviii, 1929, p. 84). Drawings of the buccal

cavity and pharynx, which are strikingly different in the two species, are given for comparison.

The buccal armature of *P. simillimus* (text-fig. 6) consists of a row of about twenty blunt teeth standing on a straight line or on a very shallow arc; there is no pigmented area. In *P. decipiens* there are 12–14 pointed teeth, of which the lateral ones are very broad and the median ones very narrow, this difference between median and lateral teeth being more marked than in any other known species; the pigmented area is roughly triangular with a process at the middle of the posterior concave margin (text-fig. 5).

The pharynx of *P. decipiens* is very slender with a few ridges in the posterior portion. That of the female of *P. simillimus* is nearly heart-shaped, being five times as broad posteriorly as anteriorly and bearing a great number of very fine teeth which stand on pigmented areas (text-fig. 6, *b*). It is verv similar to that of *P. minutus* (Plate xxiii, fig. 1).

The spermathecae of *P. simillimus* are elliptical capsules with a wide duct, those of *P. decipiens* cylindrical capsules with a wide duct.

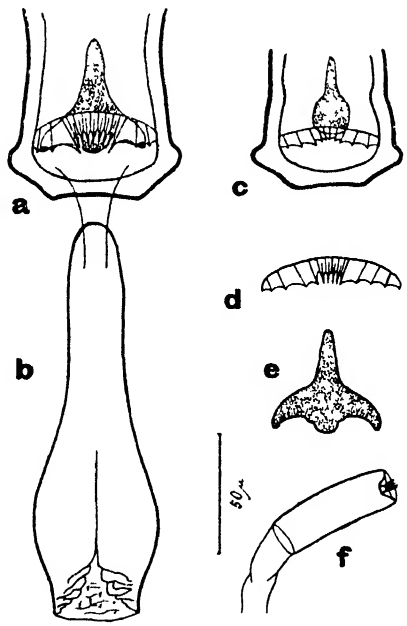

Fig. 5. *Phlebotomus decipiens*: *a*, buccal cavity, and *b*, pharynx, of ♀; *c*, buccal cavity of ♂; *d*, a different aspect of buccal armature of ♀; *e*, pigmented area in buccal cavity of ♀; *f*, spermatheca.

Phlebotomus simillimus, Newstead 1914.

P. brodeni, Parrot 1930 (n. syn.).

♂ Size: 2·3 mm. Palp formula: 1, 2, 3, 4, 5. Antennae: segment 3=4+5, and much longer than epipharynx (1·6 : 1). Wings: length, 1·8 mm.; breadth, 0·44 mm.; index $a/\beta=1$.

Buccal cavity with the armature consisting of a row of about 18 teeth with short points; no pigmented area. Pharynx slender, with a number of well-marked small

blunt teeth in the posterior portion. Genitalia with the proximal segment of the superior clasper about twice as long as the distal one; four terminal spines on the distal segment; the small anterior spine inserted at about the limit of the fourth and apical fifth of the segment; median appendage blunt; penis conical, with blunt tip; inferior clasper about two-thirds of the length of the superior one, markedly longer than the median appendage.

There are a number of differences in the buccal cavity, pharynx, spermathecae and male genitalia which distinguish *P. decipiens* from this species. The four spines on the distal segment of the superior clasper are terminal in *P. simillimus*, while in *P. decipiens* two are subterminal. The median appendage is blunt in *P. simillimus* and hooked in *P. decipiens*. The inferior clasper is relatively much shorter in *P. decipiens* than in *P. simillimus* (text-fig. 3, *c*, *d*).

Material examined: 1 ♀, 1 ♂, Kintampo, Ashanti, in latrine, vii. 1913 (*A. Ingram*).

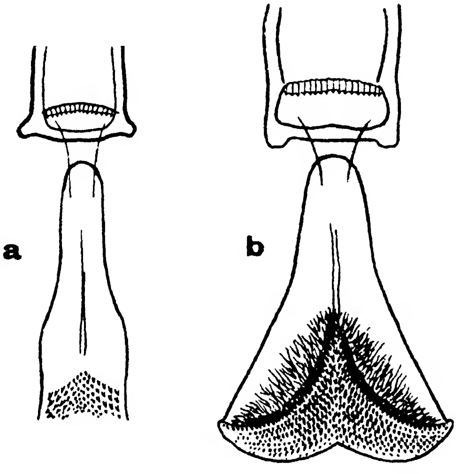

Fig. 6. *Phlebotomus simillimus*, buccal cavity and pharynx of: *a*, male, *b*, female.

Phlebotomus minutus, Rondani 1843.

P. signatipennis, Newstead 1914 (n. syn.).

The species *P. signatipennis* was created by Newstead on the character of the very small wing index ($a/\beta=0{\cdot}2$) in one female. An examination of several specimens from the collection of the London School of Tropical Medicine, determined by Prof. Newstead as *P. signatipennis*, did not reveal any notable differences between these specimens and *P. minutus*. The name *P. signatipennis* has therefore to be considered a synonym of *P. minutus*.

The wing index, as has been pointed out on several occasions, is a very variable character and certainly not sufficient in itself for the separation of the species. Another instance of such a small wing index has been found to occur in one specimen of *P. baghdadis*.

Material examined: 8 ♀♀, 1 ♂, Sudan.

Key for African Sandflies.

Males.

1.	No armature in buccal cavity	2
	Armature present	6
2.	Five spines on apical segment of superior clasper	3
	Four spines on apical segment of superior clasper	5
3.	Apical segment of superior clasper very long, three short terminal spines and two short spines in middle of segment	*papatasii* (*roubaudi, duboscqui*)
	Segment shorter, two long spines terminal, three long ones in middle of segment	4
4.	Penis bifid	*perniciosus*
	Penis ending in one point	*langeroni*
5.	Apical segment of superior clasper very short, with brush near base; intermediate appendage simple	*sergenti*
	No brush; intermediate appendage with two processes	*rodhaini*
6.	Penis blunt, sometimes tapering towards end	7
	Penis conical, more or less pointed	13
7.	Intermediate appendage ending bluntly	8
	Intermediate appendage ending in a hook	12
8.	Two terminal spines on apical segment of superior clasper, two spines at apical third of segment	*schwetzi*
	All four spines terminal or slightly subterminal	9
9.	Palp formula 1, 2, 4, 3, 5	*minutus*
	Palp formula 1, 2, 3, 4, 5	10
10.	Inferior clasper markedly longer than intermediate appendage	11
	Inferior clasper as long as intermediate appendage	*yusafi*
11.	About 30 pointed teeth in buccal cavity	*nairobiensis*
	About 16–18 blunt teeth in buccal cavity	*schoutedeni*
12.	Penis blunt but tapering; all four spines on apical segment of superior clasper terminal; small anterior seta at apical third of segment	*parroti*
	Penis blunt but tapering; two spines terminal, two markedly subterminal; small anterior seta, very near base of subterminal spines	*babu*
13.	Intermediate appendage blunt	14
	Intermediate appendage hooked	17
14.	Two terminal spines, two spines at middle of apical segment of superior clasper...	*ingrami*
	All four spines terminal or slightly subterminal	15
15.	Apical segment of superior clasper 7–8 times as long as broad; small anterior seta subterminal; palp formula 1, 2, 4, 3, 5	*fallax*
	Apical segment 4–5 times as long as broad; palp formula 1, 2, 3, 4, 5 ...	16
16.	Third antennal segment longer than epipharynx (1·7 : 1)	*simillimus*
	Third antennal segment shorter than epipharynx (0·8 : 1)	*squamipleuris*
17.	Third antennal segment much longer than epipharynx (2·1 : 1); small anterior seta on apical segment of superior clasper subterminal; intermediate appendage with thickened head, hook clearly marked	*decipiens*
	Third antennal segment longer than 4+5, or than epipharynx (1·5 : 1); intermediate appendage with very slender pointed hook, as long as inferior clasper	*collarti*
	Third antennal segment shorter than 4+5, longer than epipharynx (1·1 : 1); hook of intermediate appendage not very marked; small anterior seta in middle of segment...	*africanus*

Females.

1. No armature in buccal cavity 2
   Armature present 3
2. Pharynx with a network of lines in posterior part ; spermathecae with 10–12 segments ... ... *papatasii*
   Pharynx with rows of very small point-like teeth, spermathecae with 10–12 segments and a long neck ... ... *perniciosus*
   Pharynx with very coarse teeth, spermathecae with 4–5 segments, apical segment broader than the rest ... ... *sergenti*
3. Pharynx unarmed 4
   Pharynx toothed in posterior part 7
4. Spermathecae tubular 5
   Spermathecae cylindrical capsules with wide ducts 6
5. Armature in buccal cavity consisting of three rows of teeth ... *ingrami*
   One row of about 17 broad pointed teeth in buccal cavity, median one slightly smaller than lateral ones ... ... *schwetzi*
6. Pharynx three times as broad posteriorly as anteriorly and narrowing suddenly behind the widest part ; 10–12 equal pointed teeth in buccal cavity ... ... *collarti*
   Pharynx slender ; 12–14 teeth in buccal cavity, median ones very much narrower than lateral ones ... ... *decipiens*
7. Pharynx 4–5 times as broad posteriorly as anteriorly, very many small teeth 8
   Pharynx conical, 2–3 times as broad posteriorly as anteriorly, many small pointed teeth 9
   Pharynx slender with relatively few long teeth 10
8. Spermathecae tubular ; 25–30 pointed teeth in buccal cavity, median ones narrower than lateral ones, standing on an arc concave posteriorly ... ... *minutus*
   Spermathecae elliptical capsules with wide ducts ; a straight row of 20 blunt teeth in buccal cavity ... ... *simillimus*
9. About 40 pointed teeth in buccal cavity, standing on an arc slightly concave posteriorly ; spermathecae tubular ... ... *nairobiensis*
   About 20 pointed teeth, median ones much narrower than lateral ones ; spermathecae tubular ... ... *schoutedeni*
10. Pharynx lamp-glass-shaped 11
    Pharynx conical 13
11. Spermathecae tubular ; about 70 narrow, parallel, blunt teeth in buccal cavity ... ... *parroti*
    Spermathecae round capsules with many small spines ; pharynx broad ; about 40 pointed parallel teeth in buccal cavity, standing on an arc markedly convex posteriorly ... ... *squamipleuris*
    Spermathecae elliptical capsules with narrow ducts 12
12. About 40 narrow parallel blunt teeth in buccal cavity ... ... *africanus*
    About 60 similar teeth ... ... *freetownensis*
13. About 12 equal pointed teeth in buccal cavity standing on an arc strongly concave posteriorly ... ... *yusafi*
    About 25 equal pointed teeth standing on an arc slightly concave posteriorly with a deep circular notch in middle ... ... *babu*

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Fig 1 *P yusafi*

Fig 2 *P nairobiensis*

Fig 3 *P schoutedeni*

Pharynx of Female Phlebotomus (× about 400)

Fig 1 *P minutus*

Fig 2 *P squamipleuris*

Pharynx and Buccal Cavity of Female Phlebotomus (× about 400)

PARASITES OF THE WHEAT-STEM SAWFLY, *CEPHUS PYGMAEUS*, LINNAEUS, IN ENGLAND.

By George Salt, D.Sc., F.E.S.,
Imperial Institute of Entomology.

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Introduction.

For a number of years the western grass-stem sawfly, *Cephus cinctus*, Norton, has been accounted one of the major insect pests of wheat in Western Canada. Originally a grass-feeder, it began to attack wheat about the beginning of the present century, at first only occasionally and at the edges of fields in Manitoba, later much more commonly and with a very wide distribution throughout the wheat-growing areas of Manitoba, Saskatchewan, and Alberta. While this sawfly was confined to native grasses it was held in check by two principal factors (Criddle, 1922) : shortage of grass stalks suitable for oviposition, and parasites. When, however, it began to attack wheat, both of these restraints were evaded. In the first place the wheat fields provided an abundance of host-plants. In the second place, the natural parasites of the sawfly did not move with it into the grain fields—whether they are unaware of the presence of their host in wheat plants or are unable to attack it in that situation is unknown.

While wheat continues to be the staple crop of Western Canada obviously the first of these restraints cannot exist. However, by invoking the aid of parasites that will attack the sawfly in wheat stems it is possible that the second restraint may be re-imposed and the natural balance partially restored. The problem is to find those parasites.

The true wheat-stem sawfly, *Cephus pygmaeus*, Linnaeus, has been known as a pest of wheat in Europe for many years. There is no evidence of its recent transference from wild grasses, or, indeed, that it more than rarely attacks any other plant than wheat. It seemed, therefore, that European parasites of *Cephus pygmaeus*, being adapted to a host living in wheat stems, might be of use against that portion of the *Cephus cinctus* population attacking wheat in Canada.

Accordingly, in the autumn of 1929, I began an investigation of the parasites of *Cephus pygmaeus* in England with the object of finding out what parasites there are and whether any of them is sufficiently effective to justify its introduction into Canada for the attempted control of *Cephus cinctus*. The present paper is a report of that study. The investigation has been carried on at the Farnham House Laboratory of the Imperial Institute of Entomology under the supervision of Dr. W. R. Thompson. I am much indebted to Dr. Thompson for his interest in and kind furtherance of my work. Dr. Ch. Ferrière, of the Imperial Institute of Entomology, has identified all of my material and I am very grateful to him for the time and effort he has devoted to that difficult matter. The field collections of one hundred and twenty samples and over four hundred sacks of wheat stubble were efficiently made by Mr. H. S. Hanson. Miss R. Thorne and Mrs. A. Cox have shared the monotonous task of picking the infested stalks from this mass of material. Mr. E. Basden has acted throughout as my very willing and faithful laboratory assistant. During my absence on leave a number of routine dissections were made for me by Mr. S. Kozlovsky. To all of these helpers I should like to record my thanks.

I. A General Account of the Investigation.

1. Life-history of Cephus pygmaeus.

The wheat-stem sawfly is so generally known that it should not be necessary to preface this study of its parasites with more than a very brief account of its life-history. The habits of the insect are dealt with in almost all textbooks of agricultural entomology and have recently been more fully studied by Ries (1926). The adult sawflies are on the wing in England in late June and early July. With its saw-like ovipositor the female cuts a slit in the wheat stem below the developing ear and lays an egg in the lumen. The young larva emerges in seven to ten days and bores its way down the stalk, perforating the nodes and widening the lumen by eating the surrounding tissues. Within a month, that is before the end of August, the larva is fully grown and has reached the base of the stem. There, about an inch above the ground, it makes a deep incision around the inside of the stalk so that the walls are nearly, but not quite severed. Below this incision it fills the lumen with a plug of frass and in the short cavity remaining below the plug it spins its delicate cocoon. The larva rests within its cocoon in the wheat stubble (fig. 1, *a*) from August until the following May. During May it pupates and then, in a few days, becomes adult and emerges by biting its way through the plug. There is only one generation a year. The habits of the Canadian species, *Cephus cinctus*, Norton, are essentially similar in all respects and have been studied by Ainslie (1920) and Criddle (1922, 1923).

One point in this life-history is to be especially noticed—the insect's habit of girdling and greatly weakening the stem just above its hibernation chamber. This is a deliberate action that serves the pest in at least two ways: it provides an easy exit for the adult in the following spring; and it protects the hibernating larva against browsing animals, which, if the stem did not break off at this point, might

pull up the entire stalk and crush the insect with its food. It is this same habit, however, that makes the sawfly so obnoxious to man, for upon it the economic damage of the pest depends. The ears of the grain are not materially affected by the insect's presence (Mitchener, 1928), but the infested stalks are so weakened that a strong wind or heavy rain prostrates them and they are not harvested.

2. Mass Collection of the Host.

On commencing a study of the English parasites of *Cephus pygmaeus* in the autumn of 1929, it was first necessary to find a region where the host was sufficiently plentiful. A preliminary survey of fields in the neighbourhood of the laboratory at Farnham Royal was disappointing, and samples sent from Devonshire were even less satisfactory. A small amount of stubble taken from a field at the Rothamsted Experiment Station, however, showed a promising infestation.

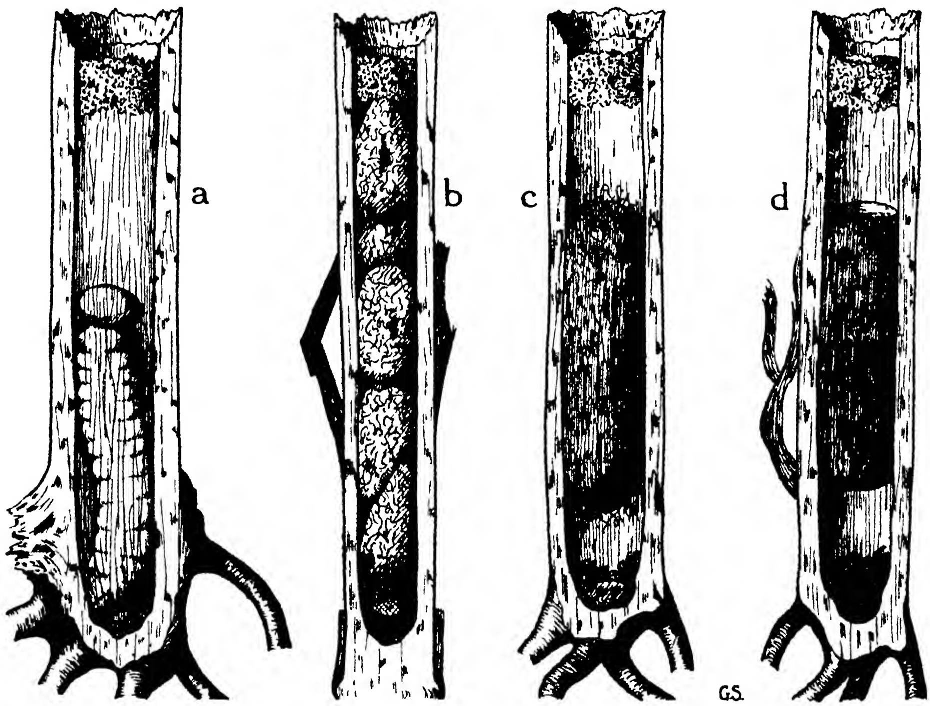

Fig 1. Hibernacula of *Cephus pygmaeus* occupied by . *a*, hibernating larva of *Cephus pygmaeus* ; *b*, cocoons of *Microbracon terebella* ; *c*, cocoon of *Hemiteles hemipterus* , *d*, cocoon of *Leptocryptus bellulus*

At the end of September 1929, Mr. H. S. Hanson was engaged to act as collector. He went first to the wheat-growing region about Harpenden, Herts., and later to that in the neighbourhood of Cambridge. From these two districts he sent more than a hundred samples representing thirty fields in the vicinity of St. Albans and Harpenden ; Woburn, Bedfordshire ; Cambridge ; and Ely. As a result of this survey four fields with a satisfactory infestation were found and fifty large sacks of stubble were taken from them. This material was stored at the laboratory at outdoor temperatures, and from it, in the course of the winter, the parasitized *Cephus* were collected for shipment to Canada.

The information obtained from the survey of 1929 rendered the procedure in the autumn of 1930 much simpler. A field at Harpenden that had been under observation during the summer and that was known to be heavily infested with *Cephus* was leased, so that early ploughing operations should not curtail the collections, and during September and October over 350 sacks of wheat stubble were taken from it.

Details of the examination of this material in both seasons are given in the second part of this paper. Here it is necessary only to summarize the results. In 1929 it was found that the average infestation of wheat stubble by *Cephus pygmaeus** in the four districts surveyed was less than 6 per cent., and in no field studied did the infestation exceed 10 per cent. In 1930 the one field studied intensively and selected for its high infestation had a stubble infestation of 9·8 per cent. This is a very different condition from that occurring in the United States, where in parts of New York and Pennsylvania *Cephus pygmaeus* infests between 5 and 76 per cent. of the wheat (Ries, 1926), and in Canada, where in 1922 over thousands of acres it was " by no means uncommon to find fields of wheat with 90 per cent. of the stems attacked " by *Cephus cinctus* (Criddle, 1923). The difference may be due in part to the more careful cultivation of the smaller English fields, but it is likely that it is also due in part to the activities of the parasites described below.

3. Parasites of Cephus.

Four species of parasites have been recorded as attacking *Cephus cinctus* in Western Canada and the United States, namely :—

Microbracon cephi, Gahan (BRACONIDAE, Braconinae)
Eurytoma sp. (CHALCIDIDAE, Eurytominae)
Eupelmus allynii, French (CHALCIDIDAE, Eupelminae)
Pleurotropis utahensis, Crawford (CHALCIDIDAE, Eulophinae).

These parasites, however, do not seem to have been studied in detail, and it is possible that at least one on the list, the species of *Eurytoma*, is a secondary parasite attacking *Microbracon cephi* ; while *Eupelmus allynii* has been recorded as both a primary and a secondary parasite of other hosts. In any case it is to be remembered that while some of these species are very effective against individuals of *Cephus cinctus* feeding in grass, they have unfortunately made little or no headway against it in the grain fields.

The list of parasites of *Cephus pygmaeus* is longer. In his excellent study of *Cephus pygmaeus* in the United States Ries (1926) mentions seven species reared by him from material collected in the State of New York. These parasites are :—

Hoplocryptus sp. (ICHNEUMONIDAE, Cryptinae)
Epiurus sp. (ICHNEUMONIDAE, Pimplinae)
Heterospilus cephi, Rohwer (BRACONIDAE, Hormiinae)
Eurytoma sp. (CHALCIDIDAE, Eurytominae)
Eupelmus allynii, French (CHALCIDIDAE, Eupelminae)
Eupelminus saltator, Lindemann (CHALCIDIDAE, Eupelminae)
Pleurotropis benefica, Gahan (CHALCIDIDAE, Eulophinae).

Ries simply states that these species were reared from *Cephus pygmaeus* material and gives no other information about them, so that their relative importance and

* *Trachelus tabidus*, Fabricius, an allied species of CEPHIDAE, also occurs in England in wheat stubble but with a frequency only 0·78 per cent. of that of *Cephus pygmaeus* ; that is, in less than 0·05 per cent. of the wheat stalks. Larvae of these two species can be distinguished (*cf.* Gahan, 1920), but for obvious practical reasons I could not separate them in my bulk collections. My figures of the prevalence of *C. pygmaeus*, therefore, actually refer to the infestation of both species, but the proportion of *T. tabidus* is so low that I have felt justified in disregarding its presence.

their true relation to the sawfly remain unknown. It is probable that at least one or two are hyperparasites.

In Europe only four parasites of *Cephus pygmaeus* have yet been reported :—

Collyria calcitrator, Gravenhorst (ICHNEUMONIDAE, Pimplinae) ; Europe generally (several authors).

Microbracon abscissor, Nees (BRACONIDAE, Braconinae) ; Russia (Shchegolev, 1930).

Eupelmus sp. (CHALCIDIDAE, Eupelminae) ; Russia (Shchegolev, 1930).

Arthrolysis scabricula, Nees (CHALCIDIDAE, Miscogasterinae) ; Russia (Borodin 1915 ; Shchegolev, 1930).

The *Collyria* sp. recorded from *C. pygmaeus* in Tiflis by Uvarov (1917) may be taken, in the absence of other data, to be *Collyria calcitrator*, which is known to occur in that region ; and the *C. puncticeps*, Thomson, of Shchegolev (1930) is the *C. calcitrator* of authors (see below, p. 506).

From the English *Cephus* material examined in the present study a total of thirteen species of parasites were reared. Nine of these are primary parasites and four are hyperparasites, but the division is complicated by the fact that one of the primary parasites occasionally acts as a secondary. As is obvious from the figures of their occurrence, five of the primary parasites are of major and four of minor importance. The primary parasites and their frequence per hundred *Cephus*-infested stalks are :—

Hemiteles hemipterus, Fabricius (ICHNEUMONIDAE, Cryptinae) ; 0·66.

Leptocryptus bellulus, Kriechbaumer (ICHNEUMONIDAE, Cryptinae) ; 0·02.

Microcryptus (?) unifasciatus, Schmiedeknecht (ICHNEUMONIDAE, Cryptinae) ; less than 0·0001.

Pezomachus fallax, Foerster (ICHNEUMONIDAE, Cryptinae) ; less than 0·001.

Gambrus tricolor, Gravenhorst (ICHNEUMONIDAE, Cryptinae) ; less than 0·001.

Pimpla detrita, Holmgren (ICHNEUMONIDAE, Pimplinae) ; 2·12.

Collyria calcitrator, Gravenhorst (ICHNEUMONIDAE, Pimplinae) ; 62·25.

Microbracon terebella, Wesmael (BRACONIDAE, Braconinae) ; 2·77.

Pleurotropis benefica, Gahan (CHALCIDIDAE, Eulophinae) ; 3·95.

One species attacks *Hemiteles hemipterus* as a secondary parasite :—

Hemiteles inimicus, Gravenhorst (ICHNEUMONIDAE, Cryptinae).

Four species attack *Microbracon terebella* as secondary parasites :—

Hemiteles hemipterus, Fabricius (ICHNEUMONIDAE, Cryptinae).

Pezomachus terebrator, Ratzeburg (ICHNEUMONIDAE, Cryptinae).

Eurytoma appendigaster, Swederus (CHALCIDIDAE, Eurytominae).

Habrocytus sp. (CHALCIDIDAE, Pteromalinae).

These parasites are described in detail and their habits discussed in the third part of this paper. Here it is necessary to deal with them only very briefly to show what parts they play in the control of the sawfly.

Only a negligible total of 0·02 per cent. of the *Cephus* population was found attacked by the minor parasites, *Leptocryptus bellulus*, Kriechbaumer, *Microcryptus unifasciatus*, Schmiedeknecht, *Pezomachus fallax*, Foerster, and *Gambrus tricolor*, Gravenhorst. On the basis of their incidence none of these could be considered useful for introduction.

Many stalks that had obviously been attacked by *Cephus pygmaeus* contained no sawfly cocoons and were without sign of the usual hibernation chamber at the base.

In these cases, however, upon examination of the frass filling the lumen of the stem, the larva of *Pimpla detrita* was found, usually just above the second node. It occurred in 2·12 per cent. of the infested stubble. Among the other parasitic larvae found in this study it may be easily recognized by its position among the frass high in the stem, by the curved attitude it there assumes (fig. 18, *a*), and by its prominently dentate labial ring (fig. 19). It is ectophagous and kills the host larva early in the season before the hibernaculum is prepared. This habit would seem to recommend the species, but actually it must be considered a disadvantage because, by hibernating high in the exposed stem rather than in the protected hibernaculum, many of the parasites are destroyed both when the grain is cut and later when the stubble is harrowed. *P. detrita* is not confined to *Cephus pygmaeus*, having also been recorded from several Lepidopterous hosts. For three reasons—its low percentage of parasitism, its high mortality due to its position in the stalk, and its wide and poorly understood host relationships—*P. detrita* is not a suitable parasite for immediate use against *C. cinctus* in Canada.

About 2·77 per cent. of the infested stalks contained, instead of the single large cocoon of *Cephus pygmaeus*, a group of much smaller cocoons (fig. 1, *b*), tougher in texture and light brown in colour. These were the cocoons of *Microbracon terebella*. This species is gregarious and three or four cocoons are usually found together, though there may be from one to seven. Part or whole of the *Cephus* cocoon is usually present as an outer wrapping of the *Microbracon* cocoons, showing that normally these parasites do not destroy their host until it has constructed its winter quarters. The larva of this species can be readily distinguished from the other primary parasites of *C. pygmaeus* by its gregarious habit, by its small size, and, technically, by its facial rods (fig. 24, *a*) and the Braconid characteristics of its tracheal system (fig. 23, *b*, *c*). It is ectophagous and is intrinsically superior to the endophagous *Collyria calcitrator* described below. At least four species of hyperparasites attack *M. terebella* in England. Another species of *Microbracon*, *M. cephi*, parasitizes *C. cinctus* in Canada and is very effective with individuals of that species feeding in grass, but unfortunately it has been very slow (Criddle, 1924) in moving to the grain fields. The low percentage of parasitism of *M. terebella*, its counter-effect on the more valuable parasite *Collyria calcitrator*, its liability to hyperparasitism, and the presence of an allied species already attacking *Cephus cinctus* in Western Canada, all throw doubt on its suitability for introduction either at present or in the future.

In 0·66 per cent. of the infested stalks the cocoon of *Hemiteles hemipterus* was found inside that of the sawfly. This species may be readily separated from the other major parasites of *Cephus* by its tough, dark-grey cocoon (fig. 1, *c*) and by the large size of its very flaccid larva (fig. 5, *a*). Unfortunately, it is very difficult to distinguish the larval stages and cocoon from those of some of the minor parasites; the characters that will serve this purpose are microscopic and are relegated to the third part of the paper. The species of *Hemiteles* are usually hyperparasitic and *Hemiteles hemipterus* itself is known to attack four species of beneficial parasites, including one of the other primary parasites of the wheat-stem sawfly. It is undoubtedly a primary parasite of *Cephus pygmaeus*, but it would obviously be unwise to liberate a facultative hyperparasite in Canada. In any case, the percentage of parasitism of this species does not warrant its use.

The sawfly cocoon in 3·95 per cent. of the infested stalks was found to contain the small stubby larva of *Pleurotropis benefica*. This larva is easily recognized among the other species, by its small size and stubby form, by its habit of lying naked in the cocoon of the sawfly, and by the Chalcidoid characteristics of its mouth-parts (fig. 28, *a*) and tracheal system (fig. 29, *a*, *b*). The species has already been recorded as a parasite of *C. pygmaeus* in the State of New York (Ries, 1926). Since *P. benefica* already occurs in America and since the English strain accounts for only a small part of the sawfly population, shipments to Canada from England do not seem to be worth while for the present.

In 87·51 per cent. of the cases, when wheat stalks infested by *Cephus pygmaeus* were split longitudinally, the cocoon of the sawfly was found intact at the base of the stalk and the *Cephus* larva inside it was alive and apparently healthy. When, however, these apparently healthy larvae were dissected very many of them were found to contain the larva of an endophagous Ichneumonid, *Collyria calcitrator*. Out of a total of 5,015 random dissections this parasite was found in 3,567 larvae or 71·13 per cent. Since the larvae obtained represent only 87·51 per cent. of the actual infestation, however, the effective parasitism of *Collyria calcitrator* is 62·25 per cent. of the entire *Cephus* population. This high percentage of parasitism immediately points to this species as by far the most successful parasite of *Cephus pygmaeus* in England and the most promising species to introduce into Canada for use against *C. cinctus*.

To facilitate the recognition of these species as they are found in the field between September and April, when the collections are made, I have drawn up the following key based on characters easily observed and requiring no lens. More accurate and complete keys to both the larvae and the adults of the parasites will be found at the beginning of the third part of this paper.

Field Key to Parasites as they are found in Stubble between September and April.

1. Host larva not destroyed. Parasite larva endophagous and only to be obtained by dissection of the host larva. Parasite larva (fig. 14, *b*) 3·5 to 5·5 mm. long, flattened, very delicate and without any darkened facial rods but usually accompanied in the host by the hard, dark head-capsule (fig. 13, *a*) of its earlier stage ... ... *Collyria calcitrator.*
   Host larva destroyed, only its remains or not even these to be found in the infested stem 2
2. Parasite larva not enveloped in a cocoon but lying naked among the particles of frass in the wheat stalk, usually above the second node: 6 to 7 mm. long, fusiform, lying in a characteristic curved position (fig. 18, *a*) *Pimpla detrita.*
   Parasite larva enveloped in a cocoon, either one of its own construction or that of its host 3
3. Parasite gregarious; usually 3 to 5 small brownish cocoons (fig. 1, *b*), 4 mm. long, arranged one above the other, either enveloped by the cocoon of *Cephus* or by fragments of it or free; these small cocoons containing larvae 2·5 to 3·5 mm. long (fig. 23, *a*) ... ... *Microbracon terebella.*
   Parasite solitary... 4
4. Parasite larva enveloped only by the thin cocoon of its host, spinning no cocoon of its own; small but stout, about 3·5 mm. long and 1·5 mm. wide; head (fig. 28, *a*) with only the mandibles dark ... *Pleurotropis benefica.*
   Parasite enclosed in a cocoon of its own making, usually inside the cocoon of its host 5
5. Parasite larva within a light brown cocoon of its own construction, usually also enveloped by the host cocoon; small, not over 3·5 mm. long (fig. 23, *a*). . . . occasional solitary individuals of ... ... *Microbracon terebella.*
   Parasite larva in a tough, dark-grey cocoon of its own construction invariably surrounded by the thin transparent cocoon of its host (fig. 1, *c*); larva 4 to 5 mm. long (fig. 5, *a*). ... ... *Hemiteles hemipterus* (or . rarely one of the minor parasites).

These parasites having been found, it was necessary to select that or those to be introduced into Canada for use against *Cephus cinctus*. From the point of view of its frequence, *Collyria calcitrator* stood out far above the others, since it attacked 62·25 per cent. of the *Cephus* population, while the next commonest parasite, *Pleurotropis benefica*, accounted for only 3·95 per cent. In several other respects, too, this species seemed highly satisfactory. First, *Collyria calcitrator* is known to occur in Russia,

where the climate is continental and very similar to that of Western Canada. Probably, therefore, the species can be successfully established in the New World. Secondly, *Collyria calcitrator* is a very specialised Ichneumonid and has been recorded only from *Cephus pygmaeus* and *Trachelus tabidus*, two Cephids whose larvae bore in wheat stems. It is likely, then, that the parasite is strictly dependent upon these or similar hosts and will not dissipate its energy. Moreover, since *Cephus cinctus* is more closely allied to *Cephus pygmaeus* than is *Trachelus tabidus*, it may be expected that *Collyria* will attack the Canadian species. Thirdly, no hyperparasites of *Collyria calcitrator* have been recorded and none was found in the present study. Fourthly, no close relative of *Collyria calcitrator*, with which it might have to compete, is known to occur in the New World. Each of the other parasites, on the other hand, has certain undesirable traits which have been pointed out above. The evidence, then, was overwhelmingly in favour of the introduction of *Collyria calcitrator* ; indeed, it seemed that this was not only the best species to use but also the only one that it was advisable to introduce for the present.

4. Mass Collection and Shipment of Collyria calcitrator.

Collyria calcitrator having been selected for introduction it remained to collect and send as large a consignment of the parasite as possible. With the experience gained in the examination of the samples this was a comparatively easy matter involving merely routine work. However, as it is very likely that further shipments will be necessary, the method adopted is described for the guidance of those who will have to make them.

It has already been mentioned that fifty large sacks of stubble were collected in October and November, 1929, from the four fields showing the highest *Cephus* infestation. At the beginning of January the collection of *Collyria calcitrator* from this stubble was commenced. The first three sacks were done exactly as the samples had been treated previously—the stalks were all examined and those containing *Cephus* larvae were selected. It was found that this required about twenty-five hours' work for each sack, far longer than we could afford to spend in obtaining the three or four hundred *Cephus* larvae yielded by each.

For the fourth sack another method was adopted. The stubble was carefully separated and the " stubs ", those broken off short about an inch above the roots, were placed on one side. These stubs were then examined and it was found that a very high proportion of them contained *Cephus* larvae. Then the remaining stubble, with stalks about six inches long, was examined, and only a very low infestation was found. The figures for the two lots are as follows :—

911 stubs	...	531 infested	...	53·5 per cent. infestation.
2,833 stalks	...	97 infested	...	3·4 per cent. infestation.

Moreover, it was the longer, uncircumcised stalks that contained the parasite *Pimpla detrita* and the dead *Cephus* larvae attacked by fungi, so that although 97 of the 2,833 stalks were infested, only 44 *Cephus* larvae were obtained from them for shipment. The separation and examination of the stubs required only about ten hours. In brief, the stubs contained about 90 per cent. of the *Cephus* larvae required for shipment and were separated and examined in two-fifths of the time necessary to do all the stalks. Obviously the saving was very great and from the remaining forty-six sacks only the stubs were used.

As the infested stubs were selected they were cleaned as far as possible of adhering soil and the roots were cut off short so that the selected material should occupy as little bulk as possible and so that the chance of contamination should be reduced. As a check on the infestation of these *Cephus* larvae by *Collyria calcitrator*, a few larvae were dissected from time to time. The parasitism remained almost constant

throughout, varying only between 50 and 60 per cent. A total of 214 larvae from these sacks were dissected; 121, or 56·5 per cent. contained *Collyria calcitrator*.

In this manner the collection of *Cephus* larvae from the fifty sacks of stubble was completed early in March, by which time over 17,000 stubs containing *Cephus* larvae had been collected. About 2,000 of these were retained for experimental purposes at the Laboratory. The remaining 15,000 stubs, packed in tins each containing 1,000 and in strong wooden boxes, were shipped to Canada on 20th March 1930.

The second season's work, completed just as this paper goes to press, has been on a much larger scale. Over 350 sacks of stubble have been used and the work of collecting the sawfly larvae from this material has occupied the entire time of three assistants for six months. Seven sacks of stubble were examined in detail, so that the true infestation figures could be obtained; from all the remaining stubble only the short stubs have been used, as described above. Over 110,000 infested stalks have been examined. In about 6,000 of these the *Cephus* larva was crushed, mouldy, or missing; about 6,000 stalks contained unwanted species of parasites; and nearly 8,000 *Cephus* larvae were accidentally broken out of their cocoons during the collection and thereby rendered unfit for shipment. Most of these, however, were used for control dissections and experiments. 89,600 *Cephus* larvae enclosed in unbroken hibernacula and suitable for shipment were obtained. As shown by 4,678 control dissections, 71·9 per cent. of these sawfly larvae are probably infested with *Collyria calcitrator*; the shipment, therefore, can be expected to yield nearly 65,000 individuals of the parasite. Packed as before, in tins inside strong wooden boxes, all of these 89,600 larvae were shipped to Canada on 24th April 1931.

II. Notes on *Cephus pygmaeus*, Linnaeus.

1. Status of Cephus pygmaeus in England in 1929.

As a preliminary to the mass collection of stubble in 1929 a survey was undertaken to discover fields in which the host was sufficiently prevalent to make the collection of parasites profitable. In the course of that survey a great deal of incidental information concerning the prevalence and distribution of *Cephus pygmaeus* was obtained, and since no detailed account of the sawfly infestation in England has yet been published, some of that information is recorded here.

Early in September 1929, samples of wheat stubble were collected from two fields in the neighbourhood of the Laboratory at Farnham Royal, Bucks. In this district, however, wheat is grown only in small isolated fields and not consistently for many years, so that the sawfly is unable to build up a large population, and less than one per cent. of the stalks examined were infested. Several samples of stubble from fields near South Molton, Devonshire, were then obtained. No trace of *Cephus* was found in a careful examination of 600 stalks. These stalks, however, were very slender and may have been unsuitable for the sawfly on that account, so that it must not be taken from these data that *Cephus pygmaeus* was absent from the Devonshire fields. During October, 31 samples of wheat stubble representing 13 fields in the vicinity of St. Albans and Harpenden, Herts., and Woburn, Bedfordshire, were received at the Laboratory. These were followed by 80 samples of wheat and 5 of barley stubble collected by Mr. Hanson from fields in the neighbourhood of Cambridge and Ely. In all, 120 samples consisting of between 200 and 400 stalks each and representing 42 fields in four different districts of England were examined.

In the examination of the samples of stubble at the Laboratory each stalk was split longitudinally. Infested stalks were immediately recognizable by the particles of frass in the lumen and by the perforated nodes. Very often they had already broken off at the annular incision made by the larva and only the stub immediately above the roots containing the cocoon of *Cephus* was found. So that these stubs and the broken straws belonging to them should not be counted twice and upset the

figures given below, the lower part of the stalk immediately above the roots, whether an upper stalk was attached or not, was made the basis of all counts.

It will be noticed that the infestation figures given in this section are based upon the examination of stubble, not of complete stalks. As will be shown below (page 492), such figures do not necessarily represent the true infestation of the wheat plants. They do, however, represent the "economic" infestation, since only the sawflies that have so far completed their development at the time of cutting as to be in the stubble have an economic effect.

Of the forty-two fields from which samples were taken, the five having the highest infestation were :—

Field	No of samples	No of stalks examined	No. of stalks infested	Per cent. infestation
Red Cross Field, Cambridge	7	3,093	292	9·4
Bury Field, Harpenden...	3	16,466	1,539	9·3
Harrier's Field, Cambridge	6	1,838	160	8·7
Hill Field, Cambridge	1	470	37	7·9
Neather Hall Field, Cambridge . .	7	2,347	180	7·7

It was from the first four fields that the fifty sacks of stubble were collected to supply parasites for the first shipment. The figures for Bury Field include three samples together with three sacks from the bulk collections.

The general average infestation of *Cephus pygmaeus* is shown by the following summary :—

	No of stalks examined	No of stalks infested	Per cent. infestation
Wheat—			
Farnham Royal District	663	6	0·9
North Devon	600	0	0
Harpenden District	22,143	1,734	7·8
Cambridge District	25,214	1,301	5·2
Total	48,620	3 041	6·25
Barley—			
Cambridge District	3,087	0	0

These figures give some idea of the *Cephus* infestation in four regions in England in 1929, although it must be borne in mind that search was being made for a high infestation and on that account the figures obtained are probably considerably higher than an impartial survey would show. It may be taken, then, that the average infestation of wheat stubble by *Cephus pygmaeus* in the four districts surveyed in 1929 was less than 6 per cent., and in no field studied did the infestation exceed 10 per cent.

2. Status of Cephus pygmaeus in a single Field in 1930.

No survey comparable with that of 1929 was undertaken in the season of 1930. Instead a more intensive study of the *Cephus* infestation was instituted in Bottom Common Field of Falconer's Farm, Harpenden. This rectangular field consists of twelve acres situated on a gradual slope having a north-western exposure. On the western side it is separated only by a hedge from Bury Field, which was heavily infested with *Cephus pygmaeus* in 1929 (see above). The soil is a loamy clay with

flints overlying chalk. During the three years 1925 to 1927 the entire field was sown to sainfoin; in 1928 this was ploughed in and the ground left fallow; in 1929 the southern half of the field was sown to oats, the northern half to mangels. In 1930, the southern half supported "winter" wheat sown in October, the northern half "spring" wheat sown together with clover in February. The wheat sown in both cases was of the variety "Red Standard." For use as an experimental plot 50 square yards were leased in July 1930. The plot was about five yards from the western edge of the field and so situated that the northern half of it was of spring- the southern half of winter-sown wheat. Each week from the middle of July until the end of August the wheat plants were removed and examined from four separate square yards, two in each half of the plot. All of the following notes refer to this plot or to the field as a whole.

(*a*) *Infestation of spring- and winter-sown wheat.*

The samples removed from the experimental plot are summarised in Table I. Each recorded sample represents all the stalks from two square yards, so that the total represents all the stalks from twenty-eight square yards, fourteen of spring- and fourteen of winter-sown wheat.

TABLE I

Summary of the Infestation of Samples from the Experimental Plot

Date	Winter Wheat			Spring Wheat			Winter & Spring Wheat		
	No of stalks	No of stalks infested	% infestation	No of stalks	No of stalks infested	% infestation	No of stalks	No of stalks infested	% infestation
15.vii 30	363	92	25·4	436	54	12·4	799	146	18·3
22 vii 30	400	73	18·3	523	61	11·7	923	134	14·5
29 vii 30	314	59	18·8	469	59	12·6	783	118	15·1
5 viii 30	338	49	14·5	406	66	16·3	744	115	15·5
12 viii 30	355	67	18·9	383	63	16·4	738	130	17·6
20 viii 30	429	40	9·3	458	50	10·9	887	90	10·1
29 viii 30	311	33	10·6	370	23	6·2	681	56	8·2
Total . .	2,510	413	16·5	3,045	376	12·3	5,555	789	14·2

It will be observed that the winter-sown wheat was more heavily infested than the spring-sown wheat.

(*b*) *Infestation and topography.*

On three different occasions comparable samples of winter-wheat stubble were collected from the eastern (high) part of Bottom Common Field and from the western (low) part. The difference in altitude between the sources of the "high" and "low" samples was about fifty feet. The infestation of the three pairs of samples together was as follows:—

	No. of stalks examined	No of stalks infested	% infestation
High part	2,319	105	4·5
Low part	1,985	213	10·7

On each occasion and in the total the stubble from the lower part of the field was about twice as heavily infested as that from the higher part.

(*c*) *Infestation of thick and thin stalks.*

Zolotarevsky (1915) has pointed out that in Russia *Cephus pygmaeus* prefers to oviposit in fully formed stalks. Observations made in the course of the survey of 1929 suggested that the size of the stalks was in some way correlated with their infestation in England. Accordingly the wheat plants collected in 1930 from the experimental plot were first divided arbitrarily into two groups according to their thickness. When these two groups were examined for *Cephus* infestation, the following result was obtained :—

	No. of stalks examined	No of stalks infested	% infestation
Thick stalks	4,448	760	17·1
Thin stalks	1,107	29	2·6
Total	5,555	789	14·2

It will be seen that the stalks described as thick, which included the majority of the stalks and therefore the normal ones, were very much more heavily infested than those described as thin. This fact seems to be the key to an understanding of the distribution of the *Cephus* infestation in the fields.

(*d*) *Influence of the condition of the stalks on the infestation.*

There can be no doubt that the condition of the wheat plants at the time of oviposition greatly influences their selection by the ovipositing sawflies. In the preceding section it was shown that the thick stalks are very much more heavily infested than the thin ones. What factor it is that renders them more suitable is not known. It may be actually the thickness of the stalk, or it may be its succulence, or its age, or the state of development of the ear. Whatever be the factor it seems to be connected in some way with the thickness of the stalk and the resulting infestation can be correlated with that condition.

When, now, the different infestation of winter and spring wheat and of wheat from high and low parts of the field is considered in respect to this different infestation of thick and thin stalks, the three observations may be readily reduced to a common basis. Since a certain condition of the thicker stalks of wheat attracts the ovipositing sawflies it is not surprising that the wheat in the lower part of the field is more heavily infested, for it is there, especially early in the growing season, during oviposition, that the wheat stems are larger and more succulent. Also the higher infestation of winter wheat is similarly attributable to its more advanced development, *i.e.*, its larger size, at the same period.

In Table I it is very noticeable that the infestation of winter wheat gradually fell off from the middle of July until the end of August, while that of the spring wheat increased during July, then, after reaching its peak in the first part of August, also fell off towards the end of the month. Presumably the gradual decline of the infestation of both classes in the later stages is due partly to mortality among the larvae (see below, page 491) and partly to the appearance of new stems by tillering. The difference in the progress of the infestation in the two classes, however, requires explanation. This, again, is to be found in the different condition of the wheat stems during the oviposition period. It is highly probable that in Bottom Common Field at the beginning of the oviposition period (which lasted, in 1930, from the last week in June until the middle of July) the spring-sown wheat was not suitable and was passed over by the ovipositing sawflies, which therefore were concentrated on the winter wheat. Later in the period the spring wheat became suitable and its

infestation rose, but never so high as that of the winter wheat. No figures are available for June and the early part of July to prove this hypothesis, but it is strongly supported by the fact that in the three pairs of samples taken from the experimental plot in July, 34·9 per cent. of the spring-wheat stalks were classed as thin, while only 19·5 per cent. of the winter-wheat stalks were still in this condition. The difference was probably even greater earlier in the season. Evidence of the working of the same principle is shown by the observation of Zolotarevsky (1915) that since fully formed stems are preferred for oviposition, *Cephus pygmaeus* in Russia infests principally winter-sown wheat, while *Trachelus tabidus*, which flies later, finds spring-sown crops developed to a suitable stage for oviposition.

In short, it is plain that the distribution of *Cephus pygmaeus* within the fields is largely determined by the suitability of the wheat plants for oviposition ; this suitability depending upon some condition of the plant not definitely known but certainly closely correlated with the thickness of the stem.

(*e*) *Influence of cutting on the infestation.*

The sixth series of samples in Table I were collected on 20th August. On this day the wheat in Bottom Common Field was cut ; indeed, the samples were collected within a few minutes of the time they would normally have fallen under the binder. In these samples, therefore, it was possible to determine exactly the difference between stalk and stubble infestation. As each infested stalk was examined it was noted whether the *Cephus* larva within was above or below the point at which the stalk would have been cut. The result follows :—

	Stalks infested	Insects above point of cutting	% of insects above point of cutting
Spring wheat ...	50	13	26
Winter wheat	40	8	20

It is to be observed, first of all, that between 20 and 26 per cent. of the *Cephus* larvae would have been cut off with the straw and would therefore have been unable to complete their development. It appears, then, that a considerable proportion of the sawfly population is normally thus destroyed. This fact has already been recognized and turned to account by the Canadian entomologists who recommend (Criddle, 1922) the early cutting of infested fields, so that the wheat shall be harvested before the stalks have been circumcised and so that as many larvae as possible shall be cut off with the straw and thus destroyed.

Secondly, it becomes apparent at once that the infestation of stubble as considered in the survey of 1929 is very different from the actual infestation of the growing grain and that the complete infestation is invariably higher and sometimes considerably higher than that revealed by an examination of stubble. The infestation of the 887 stalks examined in these samples was 10·1 per cent., but the stubble infestation of these same samples, the 21 insects above the point of cutting being neglected, was only 7·8 per cent. This point is discussed in the next section.

Thirdly, in connection with the explanation suggested above (p. 490) for the different infestation of spring and winter wheat, it is interesting to notice that the sawfly larvae in the winter wheat were in fact more advanced in their development than those in the spring wheat, for 80 per cent. of them had passed into the stubble, while only 74 per cent. of those in the spring wheat were so far advanced.

Fourthly, it is instructive to examine the influence of the cutting on the parasites. Of the 21 sawfly larvae that were cut off with the straw only 16 were alive. One was dead and attacked by a fungus, one was represented by three cocoons of *Microbracon terebella*, and three were represented by the larvae of *Pimpla detrita*. In the total number of 90 infested stalks there were five groups of cocoons of *M. terebella*, which therefore lost 20 per cent. of its population by cutting. *Pimpla detrita* suffered even more severely, however, for of five present in the 90 infested stalks, three were cut off in the straw. The habit of *P. detrita* of killing its host early in the season before it has descended to the base of the stem thus leads to the destruction of a large proportion of its own population and seriously impairs the value of this parasite in the control of the sawfly.

(f) The stubble infestation of Bottom Common Field.

Seven sacks of winter wheat stubble collected in different parts of Bottom Common Field in September included 32,544 stalks, of which 3,190 or 9·8 per cent. were infested. The samples taken from the experimental plot between 15th July and 29th August (Table I) included 5,555 stalks, of which 789 or 14·2 per cent. were infested. The difference between these two figures may be accounted for in general by two factors: (1) the gradual decline of the infestation due to a natural mortality; and (2) the influence of cutting.

Though the difference may be explained, as suggested above, or even measured, as in the preceding section, it would seem on a first consideration seriously to invalidate the infestation figures obtained from an examination of stubble. Actually, however, this is not the case; indeed, it seems to the writer that the stubble infestation is the better standard upon which to compare infestations of *Cephus*.

In the first place, it is the only standard that can be applied on a large scale, for while the stubble infestation remains practically the same for a long period after the wheat is cut and thus permits an extensive survey dealing with many stalks from many fields, the stalk infestation during the summer season is constantly changing, either developing or declining, so that only samples taken within a short time, and therefore limited in size, would be comparable.

In the second place, since the economic damage of the sawfly depends simply upon its habit of girdling the stem when it constructs its hibernaculum at the base, those larvae cut off with the straw, not having performed this act, have done no appreciable damage. They are, then, of little economic importance, especially as they are destroyed and do not live to reproduce in the next season. Therefore, although the stubble infestation is not a true measure of the infestation of the growing grain, it does, more truly than the stalk infestation, indicate the economic status of the pest.

III. Descriptions of the Parasites.

1. Introductory Remarks and Keys.

The species of parasitic Hymenoptera that one may expect to rear from material of *Cephus pygmaeus* in England are thirteen in number. Nine are primary parasites and four hyperparasites, but one of the primary parasites occasionally acts as a secondary. These thirteen species are discussed in this part of the paper in the following order:—

Hemiteles hemipterus, Fabricius, primary; 0·66 per cent. parasitism.
Hemiteles inimicus, Gravenhorst, secondary on *H. hemipterus*.

Leptocryptus bellulus, Kriechbaumer, primary; 0·02 per cent. parasitism.

Microcryptus (?) *unifasciatus*, Schmiedeknecht, primary; less than 0·001 per cent. parasitism.

Pezomachus fallax, Foerster, primary ; less than 0·001 per cent. parasitism.
Gambrus tricolor, Gravenhorst, primary ; less than 0·001 per cent. parasitism.
Collyria calcitrator, Gravenhorst, primary ; 62·25 per cent. parasitism.
Pimpla detrita, Holmgren, primary ; 2·12 per cent. parasitism.
Microbracon terebella, Wesmael, primary ; 2·77 per cent. parasitism.
  Hemiteles hemipterus, Fabricius, secondary on *M. terebella.*
  Pezomachus terebrator, Ratzeburg, secondary on *M. terebella.*
  Eurytoma appendigaster, Swederus, secondary on *M. terebella.*
  Habrocytus sp., secondary on *M. terebella.*
Pleurotropis benefica, Gahan, primary ; 3·95 per cent. parasitism.

As may be seen from the above list, five of the primary parasites, *Collyria calcitrator* (62·25 per cent.), *Pleurotropis benefica* (3·95 per cent.), *Microbracon terebella* (2·77 per cent.), *Pimpla detrita* (2·12 per cent.), and *Hemiteles hemipterus* (0·66 per cent.), are common and may be considered the major parasites of *C. pygmaeus* in England ; one, *Leptocryptus bellulus* (0·02 per cent.), is uncommon ; and three, *Microcryptus unifasciatus*, *Pezomachus fallax*, and *Gambrus tricolor*, are very rare, each having occurred only once in over 110,000 infested stalks. One hyperparasite, *Hemiteles inimicus*, attacks *Hemiteles hemipterus*. Four hyperparasites, *Hemiteles hemipterus*, *Pezomachus terebrator*, *Eurytoma appendigaster*, and *Habrocytus* sp., attack *Microbracon terebella.*

When wheat stubble infested with *Cephus pygmaeus* is selected as described in the first part of this paper, three other species of parasitic Hymenoptera are likely to emerge from it, namely, *Microbracon exhilarator*, Nees, *Trichacis didas*, Walker, and *Polygnotus pleuron*, Walker. These are not parasites of *Cephus pygmaeus*. The two Proctotrypids probably attack the Cecidomyiidae that occur abundantly in wheat stubble ; the host of the *Microbracon* is unknown.

The thirteen species of parasitic Hymenoptera actually concerned in the *Cephus* biocoenose, as well as the three mentioned above, may be distinguished by means of the following key. This key does not purport to be valid for general systematic purposes and is designed solely to enable an investigator to discriminate easily between parasites he may expect to rear from English *Cephus* material collected as described above.

1. Winged 2
   Completely apterous 14
2. Wings of normal length 3
   Wings very short, not or scarcely reaching beyond the apex of the first abdominal segment 13
3. Fore wings with several closed cells 4
   Fore wings without closed cells 15
4. Fore wings with only one recurrent vein ; first cubital and discoidal cells separate (Braconidae) 5
   Fore wings with two recurrent veins ; first cubital and discoidal cells confluent, forming a disco-cubital cell (Ichneumonidae) 6
5. Second abdominal tergite smooth and shining, its disc without punctation ; head and thorax black ; abdomen usually but not always with some red *Microbracon terebella.*
   Second abdominal tergite dull owing to a fine rugulose sculpture ; entirely black ... ... *Microbracon exhilarator.*

6. Fore wings with an areola 7
Fore wings without an areola; abdomen somewhat compressed; hind coxae very long ... ... *Collyria calcitrator.*

7. Areola pentagonal in shape, the outer nervure sometimes weak or wanting (CRYPTINAE) 8
Areola quadrate; abdomen sessile, depressed and closely punctate; black, legs brown, tegulae yellow ... ... *Pimpla detrita.*

8. Areola complete, its outer nervure dark 9
Areola incomplete, its outer nervure hyaline or wanting 10

9. Propodeon without longitudinal carinae, its areation indistinct; abdominal tergites distinctly punctate; mesoscutellum with a yellow mark *Gambrus tricolor.*
Propodeon with distinct longitudinal carinae, its areation distinct; abdominal tergites smooth and shining; mesoscutellum black *Microcryptus unifasciatus.*

10. Basal nervure only weakly bent inwards 11
Basal nervure strongly bent inwards (following Schmiedeknecht; this sex unknown to me) ... ... *Pezomachus terebrator* ♂.

11. Propodeon nearly naked, its posterior aspect abrupt; first abdominal segment about twice as long as its apical width 12
Propodeon clothed with whitish hairs, its posterior aspect sloping; first abdominal segment three times as long as its apical width; wings quite clear ... ... *Leptocryptus bellulus.*

12. Second abdominal tergite coriaceous, dull; lateral angles of propodeon not forming short spines; stigma wholly brown ... ... *Hemiteles inimicus.*
Second abdominal tergite shining, either smooth (♀) or striate (♂); lateral angles of propodeon forming short spines; basal half of stigma white *Hemiteles hemipterus.*

13. Female; fore wings dusky with a white mark on and below the base of the stigma; lateral angles of the propodeon forming short spines *Hemiteles hemipterus* brachypterous ♀
Male; (this sex unknown to me; according to Schmiedeknecht with insignificant rudimentary wings and mesoscutellum merely indicated) *Pezomachus fallax* ♂.

14. Propodeon with a distinct transverse carina; abdomen very closely and finely punctate; fourth antennal segment shorter than the third *Pezomachus fallax* ♀.
Propodeon without a distinct transverse carina; abdomen very sparsely punctured; fourth antennal segment as long as the third *Pezomachus terebrator* ♀.

15. Fore wings without veins (PLATYGASTERINAE) 16
Fore wings with some venation (CHALCIDIDAE) 17

16. Mesoscutum with numerous short hairs, mesoscutellum with a tuft of hairs at its apex; occipital region rugulose and dull; thorax rather finely and sparsely punctate ... ... *Trichacis didas.*
Mesoscutum and mesoscutellum naked; head and thorax very regularly, closely, and finely punctate ... ... *Polygnotus pleuron.*

17. Body with metallic green reflections 18
Body black; abdomen compressed; head and thorax with coarse sculpture, abdomen smooth and shining ... ... *Eurytoma appendigaster.*

18. Tarsi 5-segmented ; tibiae and tarsi mostly yellowish brown ; eyes oval ... *Habrocytus* sp.
   Tarsi 4-segmented ; tibiae and tarsi mostly metallic green ; eyes emarginate within ... ... *Pleurotropis benefica.*

The key to the immature stages of the five major parasites given in the first part of this paper is intended for use in the field and therefore utilizes characters not always observable at the laboratory or in preserved specimens. I cannot give a complete key to the larvae of the thirteen species of parasites based solely on their morphology, because I have not been able to study all of them. However, since the identification of parasite larvae is so important in the practice of biological control, I offer the following incomplete key which will serve to separate the full-grown larvae of six of the primary parasites.

1. Without any darkened, sclerotic parts (except the eyes of the pupa which finally became apparent through the larval cuticle), even the mandibles inconspicuous ; tracheal system without accessory lateral trunks and posterior commissure ; 6 to 10 mm. long... ... *Collyria calcitrator.*
   At least the mandibles dark, usually also with darkened facial structures 2
2. Mandibles alone darkened ; no conspicuously darkened facial structures ; 3·5 to 4·0 mm. long ... ... *Pleurotropis benefica.*
   Facial structures as well as mandibles darkened 3
3. Labial ring conspicuously dentate on its apical margin ; tracheal system with well-developed accessory lateral trunks in segments two and three and with ventral commissures in segments four to eleven ; 6 to 7 mm. long *Pimpla detrita.*
   Labial ring not conspicuously dentate apically 4
4. Mandibles, seen from above, with several prominent teeth ; frontal arch well developed ; mandibular and labial struts distinctly fused laterally ; tracheal system without accessory lateral trunks ; 2·5 to 3·5 mm. long *Microbracon terebella.*
   Mandibles not toothed, at most finely serrated ; frontal arch poorly developed ; mandibular and labial struts not distinctly fused laterally ; accessory lateral tracheal trunks present in segments two and three ; 4 to 5 mm. long 5
5. Head, above the antennae, with a pair of large swellings bearing minute infuscate papillae ; posterior arms of tentorium incomplete, not forming a continuous rod below the pharynx ; (ends of cylindrical cocoon rounded) *Hemiteles hemipterus.*
   Head, above the antennae, without prominent swellings ; posterior arms of tentorium complete, forming a continuous rod beneath the pharynx ; (ends of cylindrical cocoon abruptly truncated) ... ... *Leptocryptus bellulus.*

The primary parasites of *Cephus pygmaeus* are discussed one by one in the following pages. I have described the adults of the five major parasites in detail, largely to enable the investigator to identify his own material, but partly, I must admit, to safeguard my work in case the inevitable taxonomic changes of the future result in doubt as to the identity of the species now before me. Because I am convinced that in the discovery and use of structural characters lies the only possibility of real progress in the systematics of the parasitic Hymenoptera, I have tried to give my descriptions more of a morphological bias than seems to be usual in taxonomic descriptions in this group. My account of the thorax in each species is based on the admirable work of Snodgrass (1910) and my description of the Ichneumonid ovipositor (page 510) on his account of the honey-bee sting (1925). In the actual conduct of biological control work it is just as essential to be able to distinguish the parasites in their larval as in their adult stages. I have therefore studied the larvae

of the major parasites of *Cephus* in some detail and describe them below rather fully, both to permit their easy recognition and, further, as a contribution to that much-needed work, a monograph of the larvae of the ICHNEUMONIDAE and BRACONIDAE. This descriptive, morphological material is followed in each case by the pertinent, ethological data, which, finally, are summed up so as to indicate briefly the possible value of each species in the control of *Cephus cinctus*.

2. **Hemiteles hemipterus,** Fabricius.

The species of *Hemiteles* are usually considered to be hyperparasites, and records of their primary parasitism may well be viewed with caution. The present species, *Hemiteles hemipterus*, is itself a hyperparasite in certain cases, as will be pointed out below, but there is no doubt whatever that it acts as a primary parasite of *Cephus pygmaeus*.

Female :—Length, excluding ovipositor, 4·8 to 5·6 mm. Head in front view (fig. 2, *c*) subcircular, a little wider than high ; seen from above, distinctly narrower behind the eyes, the occipital margin concave. Vertex and cheeks separated from the occiput by a complete, low carina ; smooth and shining with only a few, widely-separated, piliferous punctures. Eyes with scattered short hairs. Posterior ocelli as far apart as from the eyes but much farther from the occipital margin ; the anterior ocellus only slightly in front of the other two. Inter-ocellar area raised ; smooth and shining. Frons above the toruli concave, smooth, with sparse piliferous punctures ; below the toruli convex, much more closely punctured. Clypeus oval in outline, twice as wide as high ; its surface convex, smooth, and shining, with only

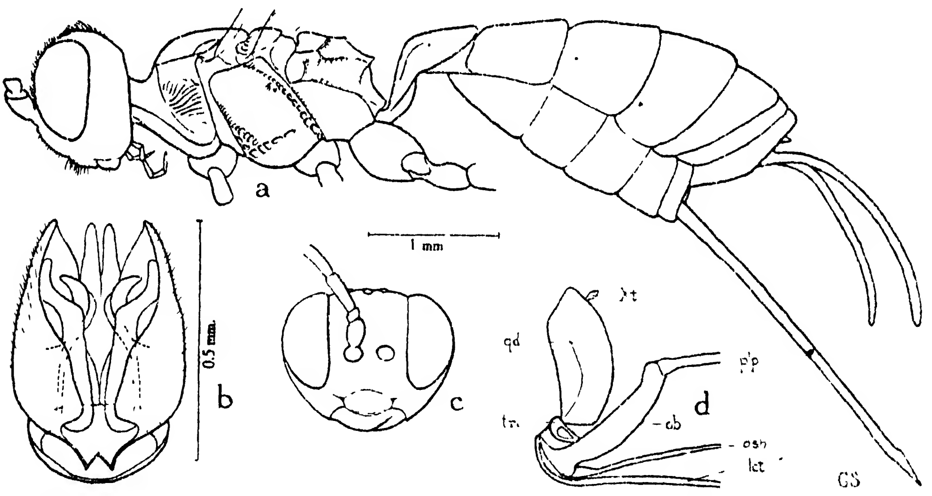

Fig. 2. *Hemiteles hemipterus*, Fabr. : *a*, side view of ♀ ; *b*, genitalia of ♂ ; *c*, front view of head of ♀ ; *d*, plates of the ovipositor–*dsh*, dorsal sheath ; *lct*, lancet ; *ob*, oblong plate ; *plp*, palpus ; *qd*, quadrate plate ; *tri*, triangular plate ; *Xt*, tenth tergite.

a few scattered piliferous punctures ; its extreme apical margin flattened. Oculo-malar space as long as the clypeus is high ; posteriorly punctured like the cheeks, anteriorly distinctly coriaceous. Toruli below the middle of the eyes ; about three-fourths their own diameter from the eyes and the same distance apart. Antennae with 20 to 22 segments ; scape swollen, punctured, and hairy ; flagellar segments becoming gradually shorter from three times as long as wide to about square ; apical segment twice as long as wide at the base, bluntly pointed. Labrum basally membranous, apically with long straight hairs. Mandibles stout, strongly

punctured basally, deeply notched apically to form two teeth of which the lower is the larger. Segments of maxillary palpi 0·16, 0·16, 0·22, 0·13, 0·16 mm. long respectively; of labial palpi 0·09, 0·09, 0·07, 0·11 mm. long respectively.

Thorax about as high as wide and twice as long as wide. Pronotum long, shining, transversely grooved; pronotal lobe concave medially, the concavity traversed by a few longitudinal and several short irregular ridges, produced below, above the proepisternum, to form a smooth, rounded keel. Mesoscutum convex but its disc flattened; notauli distinct at the anterior margin but disappearing far before the middle of the disc; parapsidal furrows absent; surface smooth and shining with very scattered piliferous punctures. Mesoscutellum deeply excavated laterally, the concavities with large quadrate pits; produced medially; punctured as the mesoscutum. Metanotum short, depressed and pitted laterally, slightly raised medially. Mesepisternum bordered by ridges, depressed within the ridges then convex over most of the disc, deeply invaginated about the spiracle; prepectus marked off by a strong ridge supported posteriorly by a series of pits; pleural and sterno-pleural sutures represented by a series of broad, more or less quadrate pits; surface of the whole smooth and shining with scattered piliferous punctures.

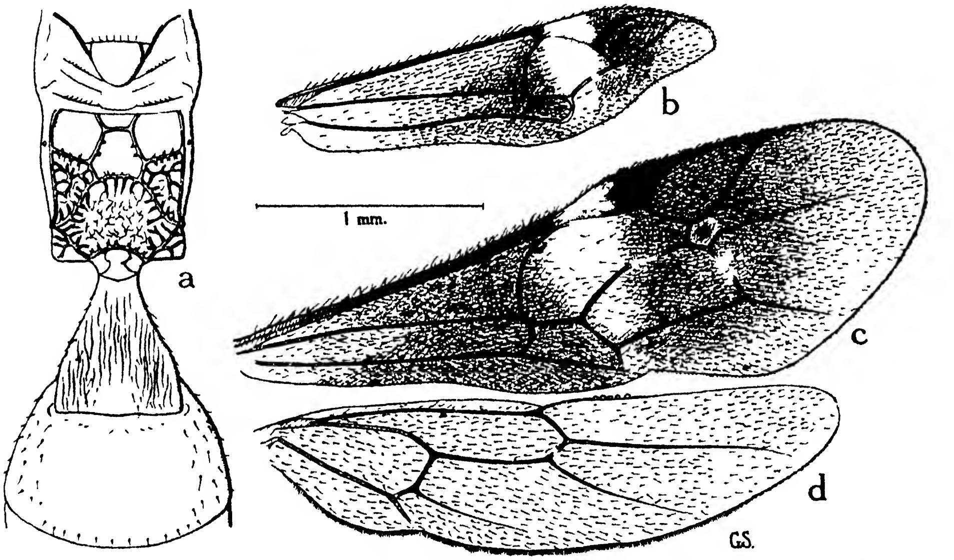

Fig 3. *Hemiteles hemipterus*, Fabr., ♀: *a*, propodeon and first two abdominal tergites; *b*, front wing of brachypterous form; *c*, front wing of macropterous form; *d*, hind wing of macropterous form.

Metapleuron much constricted dorsally, the broad ventral plate moderately punctured above, closely ridged below and posteriorly. Areation of propodeon as in figure 3, *a*; transverse carinae produced posteriorly to form two blunt spines; the spiracles small and circular; the surface smooth and shining dorsally, rather dull laterally on account of the numerous short ridges.

First abdominal segment as in figures 2, *a*, and 3, *a*; basally smooth, the disc with fine longitudinal ridges, the middle of the apex swollen, the swelling smooth and shining; spiracles behind the middle. Second and third segments very smooth, almost impunctate; succeeding segments with scattered piliferous punctures. Ovipositor when fully exserted nearly as long as the abdomen, straight, abruptly narrowed apically; palpi long and slender, almost reaching the apex of the ovipositor when it is raised at rest. Plates of ovipositor as in figure 2, *d*.

Legs stout, the coxae globular, the femora all rather swollen ; the tarsal claws strongly falcate and simple.

Front wings (fig. 3, *b*, *c*) either well-developed or very short but always reaching at least the base of the abdomen ; tegulae dark ; extreme bases of veins and basal half of stigma light yellow ; remainder of veins and apical half of stigma dark ; membrane suffused with dull brownish, lighter basally in the median and submedian cells and near the apex, almost hyaline in the middle of the discocubital and second discoidal cells below the yellow part of the stigma. Hind wings (fig. 3, *d*) hyaline ; the veins mostly light yellow ; five alar hooks ; nervellus slightly reclivous, broken a little below the middle.

Head black, scape and basal half of flagellum yellowish ferruginous, apical half of flagellum dull black. Thorax entirely black. First abdominal tergite black ; second and third, and sometimes the extreme base of the fourth, dark red ; remaining tergites black except the apical margin of the seventh which is often distinctly white ; sternites dark reddish, black posteriorly. Legs entirely yellowish ferruginous, suffused with blackish at the apices of the posterior femora and tibiae.

Hairs arising from the piliferous punctures mostly short and inconspicuous ; longer on the clypeus, and coarser on the vertex.

Male :—A little smaller and more slender than the female, from which it differs as follows : Antennae more slender, the segments of the flagellum closely and finely punctured, most of them with short longitudinal ridges, and all closely covered with short hairs. Sculpture of the thorax in general finer ; the pits representing the prepectal suture often almost wanting. Area superomedia (Schmiedeknecht) of propodeon narrower, more regularly hexagonal. Abdomen more slender ; disc of second segment closely covered with fine ridges ; basal part of disc of third segment sometimes also with a few fine ridges, generally smooth and shining with scattered piliferous punctures. Genitalia as in figure 2, *b*. Legs a little more slender. Wings always well developed, reaching the fifth abdominal segment ; almost completely hyaline but faintly infuscate at the base of the radial and at the apex of the discocubital cells. Scape and most of the flagellum black, usually only the pedicel and base of the first flagellar segment ferruginous ; sometimes the scape, pedicel, first flagellar segment, and base of the second, brown. Second and third abdominal tergites usually reddish, often suffused with black, the third frequently broadly black apically. Legs variable in colour ; mostly black, with the fore tibiae, fore tarsi, the apices of the fore femora, and bases of the middle and hind femora ferruginous ; sometimes with the fore and middle legs almost entirely ferruginous.

Although the coloration of the antennae, legs, and abdominal tergites is slightly variable in the males, as described above, and although there is sometimes a fine, obscure striation on the base of the third abdominal tergite of the males, I feel sure that only one species is concerned. I have examined a series of over 500 males and they show all gradations within the extremes and all combinations of the several variations. A few of the males might be made to run to *H. scrupulosus*, Grav., in Morley's key and might then explain Marshall's English record of that species (see Morley, 1907, p. 255). It should be noticed that the second abdominal tergite of the female is not at all striate and this sex could not therefore be correctly determined with Morley's key (1907, p. 120).

The eggs of *Hemiteles hemipterus* are deposited externally on full-grown *Cephus* larvae which are first stung to a state of paralysis. Oviposition takes place only through the cocoon of the host, which seems to provide the stimulus for the preliminaries to oviposition, for, while a naked host larva rouses no interest, an empty cocoon is examined with care and often pierced by the ovipositor. The eggs (fig. 4, *a*) are cylindrical in shape with rounded ends and slightly curved so as to appear subreniform. They measure 1·10 to 1·25 mm. in length and 0·30 to 0·35 mm. in

diameter. The surface is smooth and shining without any ornamentation. At a temperature of about 20° C. the eggs hatch within 20 hours after oviposition.

The first-stage larva (fig. 4, *b*) soon after hatching is light yellow in colour, fusiform in shape, and measures about 1·5 mm. long and 0·45 mm. in greatest width. It consists of the head and thirteen body segments, the anal segment broadly conical, not lengthened. The head is furnished with several amber-coloured sclerotized rods of which the development in the full-grown larva is fully described below. The mandibles (fig. 4, *f*), supported by these rods, consist of a simple, slightly curved tooth on a very broad subquadrate base. The antennal organs are simple, rather long and

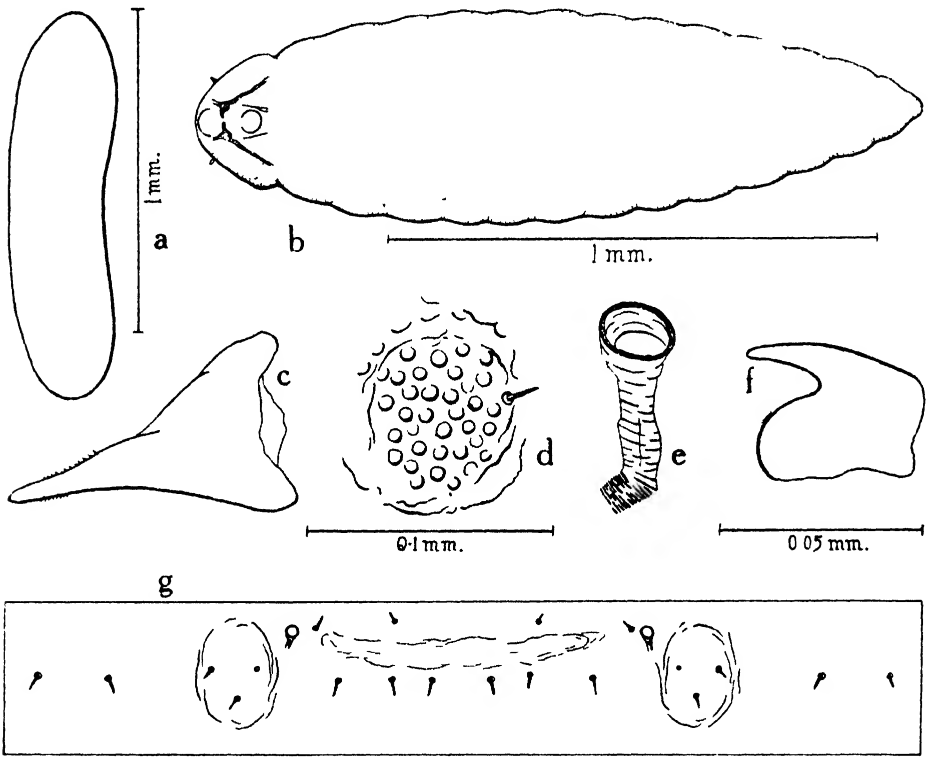

Fig. 4. *Hemiteles hemipterus*, Fabr., immature stages: *a*, egg; *b*, first-stage larva; *c*, mandible, *d*, papillate swelling on head, and *e*, thoracic spiracle of full-grown larva; *f*, mandible of first-stage larva; *g*, setal map of fifth segment of full-grown larva.

narrow papillae. There are five larval stages, all essentially similar. The mouth-parts and facial structures of the third- and fourth-stage larvae approach those of the last-stage larva in size, but the earlier stages may be readily distinguished by the bases of the labial and maxillary palpi which are simply annular and not 8-shaped as in the final stage.

The full-grown larva is white with amber-coloured mandibles and facial rods. It is stout but very flaccid, and so translucent that the dark contents of the gut are clearly visible. In outline it is regularly elliptical, about equally narrowed and rounded anteriorly and posteriorly, and considerably more convex dorsally than ventrally. In a position of rest (fig. 5, *a*) it measures 4 to 5 mm. in length, 2 to 2·5 mm. in width, and 1·5 to 2 mm. in thickness. Thirteen segments in addition to the head

are clearly distinguishable. Dorsally, segments 4 to 10 each bear a transverse, curved swelling which is also represented but obscure on segments 3 and 11. Laterally there are conspicuous hypopleural lobes on segments 4 to 11. The cuticle is shining and translucent, and except on the head and on the dorsal swellings, is covered with minute papillae which are about as high as they are wide at the base and three to four times their own width apart. In addition to these papillae the cuticle bears a few, short, inconspicuous setae; their arrangement on the abdominal segments is shown in fig. 4, *g*.

The head is large and well differentiated. Its cuticle is a little thicker and harder than that of the body segments, and almost entirely without the minute papillae with which they are covered. Dorsally it is only obscurely bilobed, but the lobes are emphasized by the presence on their apices of a pair of prominent dome-shaped swellings. The surface of these swellings (fig 4, *d*) is closely covered with small infuscate

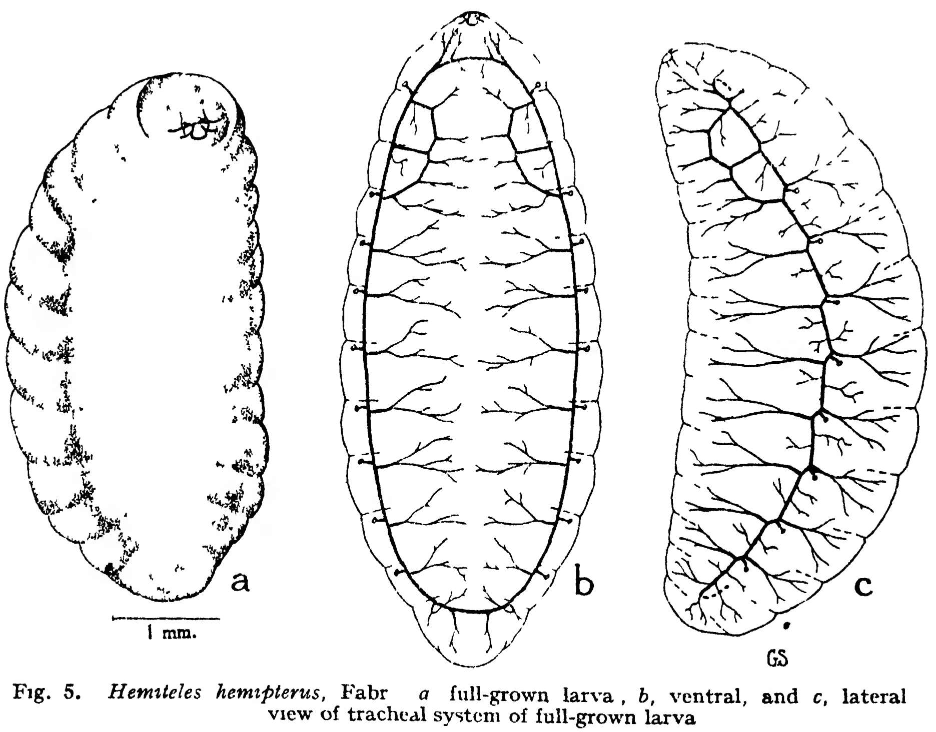

Fig. 5. *Hemiteles hemipterus*, Fabr *a* full-grown larva, *b*, ventral, and *c*, lateral view of tracheal system of full-grown larva

papillae less than their own width apart, and near the outer lateral margin of each is a single short seta. Below the swellings are the two antennal organs each consisting of a circular convex area bearing a cylindrical, somewhat cone-shaped, segment 0.03 mm. high.

The mouth-parts, with the exception of the mandibles, are poorly differentiated, soft, and colourless. The clypeus is colourless but its upper margin is defined by a darkened transverse arch. It is about four times as wide as high, and bears on each side three setae and three minute sensoria. The labrum is very poorly defined; it bears two pairs of small sensoria. The dark brown mandibles are tetrahedral in shape with the apical angle lengthened, and with the three basal angles, serving as condyles, so placed that one is ventral and two, an inner and an outer, are dorsal. The apical point is finely serrated near the tip both above and below, but on ridges

rather than on the edge, so that the teeth are difficult to make out. The maxillae are represented by two poorly differentiated, slightly swollen areas lying below the base of the mandibles. Each bears a small tuberculate process raised upon a sclerotic base having the general form of a figure eight. Near this tubercle are two setae, one on each side and a little below it. The labium is another indistinct colourless area which, however, is given a conspicuous boundary by a brown U-shaped rod under the skin beneath it. At its upper end, just below the mouth-opening, the labium receives the opening of the salivary duct. This is slightly sclerotized to form a spinneret. Below it, on each side of the labium, is a tuberculate process similar to those on the maxillae and also set upon an 8-shaped sclerotic base. Two pairs of setae are also present, one pair immediately below the tubercles and one pair near the lower lateral angles. A pair of small sensoria are found on the skin overlying the spinneret. Small setae or sensoria occur on other parts of the face; two near the side of the maxilla, six on each cheek, and three pairs between and below the antennae. Their position is shown in fig. 6, *a*.

Several darkened rods are usually conspicuous on the face of Ichneumonid larvae. Their shape and relation is constant and characteristic and they provide some of the best characters for the specific determination of these larvae. Unfortunately, although their superficial appearance—the pattern they form upon the face—has been described in several species, their true structure and relationship has never been investigated. Their function seems to be to strengthen the buccal region of the head-capsule and to afford articulation for the mandibles. Seen from inside the cranium they appear as ridges, resembling somewhat the phragmas formed by the invagination of the edges of adjacent sclerites, but their number and position is such that it is scarcely possible that they are internal ridges corresponding to external sutures. On the other hand, they do not seem to be cuticular structures, because, in part at least, the true cuticle overlies them. For their proper elucidation they require a comparative study of considerable scope and perhaps an investigation of their origin and formation, and the following account, based upon my dissections of only a few species, must be considered as being merely tentative and its purpose purely descriptive. In particular, the names applied for convenience to the various rods must not be taken to indicate any homology with the parts of the adult insect.

A pair of stout rods, which Thorpe (1930, p. 404) and I decided to call the *mandibular struts* (fig. 6, b, *m.s.*), form a condyle for the lower basal angle of the mandibles and pass laterally around the side of the head. Shortly after leaving the mandibles they give rise ventrally to a short arm, the *maxillary strut* (fig. 6, b, *mx.s*), which is unattached at its apex. At about the same point they also give rise to a dorsal arm, the *frontal strut* (fig. 6, b, *f.s.*), which passes upwards, giving off a short apophysis to support the upper angle of the mandibles. The frontal struts of the two sides are united far above the mouth-opening by a transverse arch which is only very poorly developed in *H. hemipterus* and seems to be merely a slight thickening of the cuticle, but which is very distinct in other species. The labium is demarked by a U-shaped structure, the *labial ring* (fig. 6, b, *l.r.*), immediately beneath the skin, and this in turn is supported on each side by a transverse sclerotic rod, the *labial strut* (fig. 6, b, *l.s.*). These parts constitute the main system of facial rods, but two other sclerotic structures are present. A transverse arch above the mandibles marks the upper margin of the clypeus. It does not join the frontal struts at its extremities and is not present in all the species I have examined, so that I do not consider it one of the essential structures. Far behind the mouth-opening the floor of the pharynx is darkened and thickened and gives the appearance of a curved sclerotic rod well inside the head-cavity. This, too, is not part of the main system of facial rods.

The head is further supported by the internal tentorium. At their latero-posterior extremities the mandibular struts support the stout but colourless *posterior arms* of the tentorium (fig. 6, *b*, *p.a.*). In *H. hemipterus* these are rather short and their

ends are attached to and support the pharynx. In some other species (see below *Leptocryptus bellulus* and *Microbracon terebella*) they cross the head-cavity and meet to form a continuous transverse rod below the pharynx. Not far from their lateral

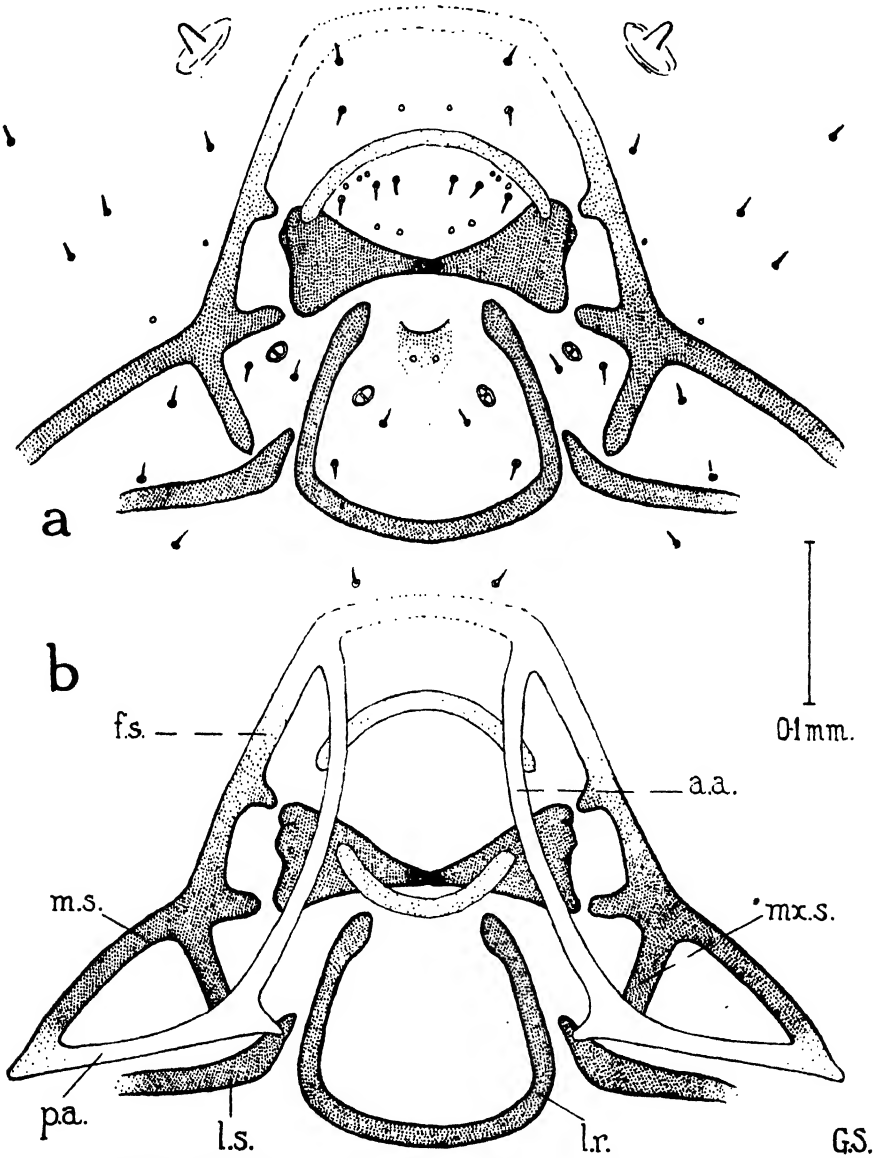

Fig. 6. *Hemiteles hemipterus*, Fabr., full-grown larva : *a*, facial rods, mouth-parts, and facial setae, seen from the front ; *b*, facial rods and tentorial arms, seen from behind—*a.a.*, anterior arm of tentorium ; *f.s.*, frontal strut ; *l.r.*, labial ring ; *l.s.*, labial strut; *m.s.*, mandibular strut ; *mx.s.*, maxillary strut ; *p.a.*, posterior arm of tentorium.

origins the posterior arms are joined by the *anterior arms* of the tentorium (fig. 6, b, *a.a.*), which pass forward and upward through the head-cavity and connect with the upper extremities of the frontal struts. In some dissections I have found traces of a pair of incomplete, colourless, and very tenuous rods leaving the anterior ten-

torial arms slightly above their middle. These might represent very poorly developed dorsal arms of the tentorium.

The respiratory system (fig. 5, *b*, *c*) communicates with the outside through nine pairs of spiracles. One pair of these (fig. 4, *e*) opens near the posterior margin of the first segment ; the remaining eight pairs near the anterior margins and just above the lateral lobes of segments 4 to 11. The lateral tracheal trunks are connected anteriorly in the first segment and posteriorly in the twelfth, and are accompanied by lateral commissures in the second and third segments. The dorsal tracheae leave the lateral trunks immediately in front of the spiracles and soon divide into two principal branches which ramify throughout the dorsal parts of the segment. The ventral tracheae leave the lateral trunks a little behind the spiracles and also divide into two principal branches. In each segment the posterior of these two branches maintains a considerable size almost to the mid-ventral line but does not meet and connect with its fellow from the other side.

The cocoon of *H. hemipterus* is spun inside that of *Cephus pygmaeus*. It is cylindrical with rounded ends. The coarse outer envelope is slate-grey in colour and very strong ; inside is a delicate diaphanous lining. The insect passes the winter in the last larval stage, pupates in the spring, and emerges during May. In the course of my work I have noted the sex of 829 emergents from isolated cocoons ; 551 were males and 278 were females—a sex ratio of 66·5 males and 33·5 females per 100 emergents. I hope to publish some notes elsewhere on the relation of the macropterous and brachypterous female forms.

Since the adult parasites emerge from their *Cephus* hosts during May and early June and do not again attack *Cephus pygmaeus* until its larvae are full-grown and have constructed their cocoons, at the end of August, it is probable that an alternate host is parasitized during the summer months. It may be for this reason that in my experiments females reared from *Cephus pygmaeus* early in the spring have consistently refused to oviposit on hibernating larvae of this same host but have readily attacked larvae of *Cydia pomonella* and *Ephialtes extensor* presented to them. Eggs laid in this manner on larvae of *Cydia pomonella* and transferred to larvae of *Cephus pygmaeus* killed by immersion in hot water were able to complete their larval development. My observations on this matter are few, but they are completely in accord and are, I believe, significant. They indicate not only the definite selection of an alternate host by the ovipositing females, but also that these females will not parasitize the host species from which they themselves developed even when it is the only one available and although it is entirely suitable for the development of their progeny.

The following are all the host records of *Hemiteles hemipterus* that I have been able to find in the literature :—

Lepidoptera

Euzophera cinerosella, Zell. (PYRALIDAE) Bignell, 1898, p. 486.
Clysia ambiguella, Hübn. (PHALONIIDAE) Schwangart, 1918, p. 554.
Polychrosis botrana, Schiff. (EUCOSMIDAE) Catoni, 1914, p. 250.
Laspeyresia microgrammana, Guen. (EUCOSMIDAE) Morley, 1907, p. 155.

Coleoptera

Hypera variabilis, Hbst. (*Phytonomus posticus*, Gyll.) (CURCULIONIDAE) Cushman, 1927, p. 12.

Hymenoptera

Hyperparasitic on *Pyrausta nubilalis*, Hübn., through
Eulimneria crassifemur, Thoms. (ICHNEUMONIDAE) and
Microgaster tibialis, Nees (BRACONIDAE) Cushman, 1927, p. 12.
Hyperparasitic* on *Clysia ambiguella*, Hübn., through
Pimpla alternans, Grav. (ICHNEUMONIDAE) Schmiedeknecht, 1905, p. 870.

* *Hemiteles hemipterus* "wurde aus *Catoptria microgramma* (= *Laspeyresia microgrammana*) gezogen, auch aus *Tortrix* (= *Clysia*) *ambiguella*, welche von *Pimpla alternans* angestochen war." Schmiedeknecht, 1905, p. 870.

The rôle of *Hemiteles hemipterus* in the *Cephus* biocoenose is complicated by its hyperparasitic tendencies. In twenty cases I have reared *Hemiteles hemipterus* from a cocoon of *Microbracon terebella*. That the species should act at once as a primary and as a secondary parasite is not surprising when its habits are analysed. As mentioned above (page 498), it is the host cocoon that provides *Hemiteles hemipterus* with the stimulus leading to oviposition. The attack on *Cephus pygmaeus* is made from the top of the hibernaculum, the ovipositor being thrust through the plug of triturated wood to the sawfly larva which is directly parasitized. Occasionally no *Cephus* larva is present in the hibernaculum but instead a group of cocoons of *Microbracon terebella*. In this case the uppermost cocoon is pierced by the ovipositor and the *Microbracon* larva it contains receives the egg and becomes the host of the *Hemiteles*. In every case the *Microbracon* cocoon from which a *Hemiteles* emerged was the uppermost of its group ; in one case two *Microbracon* cocoons lying side by side at the top of a group were both parasitized. All of the twenty individuals reared from *Microbracon* were very small ; nineteen were males, only one a brachypterous female. It should be mentioned that the males were all rather dark with very few red markings, but all were within the range of variation of the series reared directly from *Cephus pygmaeus*, and Dr. Ferrière and myself, after long study, feel sure they are identical.

Hemiteles hemipterus is itself attacked by another species of its own genus, *Hemiteles inimicus*, Gravenhorst. This parasite was reared in ten cases (9♂, 1♀) from 839 isolated cocoons of *H. hemipterus*, a frequency of 1·2 per cent. *H. inimicus* may be readily distinguished from *H. hemipterus* by the granular appearance of its second abdominal tergite and the other characters given in the key (page 494). Its cocoon is constructed of white silk with a few brownish threads and is found inside the completed cocoon of *H. hemipterus*, which again is inside the cocoon and hibernaculum of the *Cephus*. Apparently, then, *H. inimicus* attacks *H. hemipterus* late in the season, after the latter, itself a late species, has constructed its cocoon. The remains of the *hemipterus* larva are not crushed to the bottom of the cocoon but are neatly flattened against one side, between the cocoons of the two *Hemiteles*. Although I have not been able to demonstrate it to my satisfaction I think that *H. inimicus* occasionally parasitizes *C. pygmaeus* directly, as a primary parasite.

Hemiteles hemipterus is the least common of the five major parasites of *Cephus pygmaeus* in England, accounting for only 0·66 per cent. of the *Cephus* population. It is intrinsically superior to *Collyria calcitrator*, of which the hard stage-II head-capsule may often be found among the remains of the destroyed *Cephus* larva. Its host list is already fairly extensive and will probably be greatly increased. It is known already to be parasitic upon four beneficial primary parasites and probably attacks many more. For these four reasons I consider that it should not, either at present or in the future, be liberated in Western Canada.

3. **Leptocryptus bellulus,** Kriechbaumer.

Adults of *Leptocryptus bellulus* are more slender than those of *Hemiteles hemipterus* and may be readily distinguished by the sloping, pubescent propodeon, which is, moreover, without the short spines that characterize the propodeon of *H. hemipterus*. The females are always macropterous and their hyaline wings separate them from the females of the *Hemiteles*, while the wholly brown stigma, lacking the white basal mark, serves the same purposes for both sexes. The colour-markings on the abdomen are distinctly brown rather than red. In both sexes the first and second abdominal tergites are finely striate, the striae on the second tergite of the female seeming to radiate from two foci at the anterior lateral angles of the tergite.

The egg of this species has not been observed. There are five larval instars. The full-grown larva is so very similar to the corresponding stage of *Hemiteles*

hemipterus that one is embarrassed to distinguish between the two. A readily observable difference lies in the lack in this species of the two prominent swellings bearing infuscate papillae that are found on the head of *H. hemipterus*. Searching for a distinguishing character that would be of use in determining the cast skins, I could find no significant difference in the facial struts, and the facial setae and sensoria are arranged exactly as in *H. hemipterus*, except on the cheeks where one seta is displaced. The mandibles seem to be identical. The shape of the spinneret is slightly different, the dorsal emargination being deeper in *Leptocryptus bellulus*. The setae on the cuticle of the abdominal segments agree perfectly in number and arrangement. Yet, turning to the tentorial structures, I find that the posterior tentorial arms of *L. bellulus* form a continuous, well-developed rod across the head, under the pharynx. It is puzzling to find such apparently fundamental and non-adaptive structures as the tentorium differing when such minor characters as the number and position of cuticular setae are the same in the two species.

Oddly enough, the cocoons of the two species are readily separable. The cylindrical, tough, grey cocoon of *L. bellulus* (fig. 1, *d*) has abruptly truncated ends; that of *H. hemipterus* has rounded ends.

Leptocryptus bellulus occurred in only 0·02 per cent. of the infested stalks and is a minor parasite of *C. pygmaeus* in England. Among my emergents there are twice as many females as males. I have found head-capsules of second-stage larvae of *Collyria calcitrator* among the remains of *Cephus* larvae parasitized by *Leptocryptus*, which therefore is intrinsically superior to *Collyria*. No other host of *L. bellulus* seems to have been recorded.

4. **Microcryptus** (?) **unifasciatus,** Schmiedeknecht.

A single male emergent from an isolated Cephus cocoon has been determined for me by Dr. A. Roman, of the Naturhistoriska Riksmuseum, Stockholm, as *Microcryptus* (?) *unifasciatus*, Schmiedeknecht. Dr. Roman writes, "What I have called *M.* ? *unifasciatus*, Schmiedk. ♂, is Thomson's ♂ of *micropterus*, but since Thomson's ♀ is not Gravenhorst's species, I have assumed the ♂ to be the same species as the ♀, which is *unifasciatus*."

On a careful examination of the hibernaculum from which this specimen emerged, I found no trace of an intermediate host, and on this negative evidence I assume the species to be a primary parasite of the sawfly. I have not studied the cast larval skins and cannot distinguish the cocoon from that of *Hemiteles hemipterus*.

5. **Pezomachus fallax,** Foerster.

An isolated hibernaculum of *Cephus pygmaeus* yielded a female of this species—the only specimen obtained in the course of my investigations. From a study of the *Cephus* remains, on which no trace of an intermediate host was found, I am reasonably certain that *Pezomachus fallax* is a primary parasite of the sawfly. I know of no other host of the species. Its larval skins were not studied. Its cocoon is very similar to that of *Hemiteles hemipterus*.

6. **Gambrus tricolor,** Gravenhorst.

Only a single female of *Gambrus tricolor* was reared from over 110,000 infested stalks collected at Harpenden, Herts. It emerged from an isolated hibernaculum and after a careful examination of the cocoon and the remains of the *Cephus* larva I felt reasonably certain that the species was a primary parasite. This assumption was later corroborated by the French specimen mentioned below. The *Gambrus* cocoon, constructed inside that of the *Cephus*, is similar to the cocoon of *Hemiteles hemipterus* in size and shape but more delicate and lighter in colour. Its larval skins have not been studied.

Although the species is exceedingly rare in *Cephus* material in England (its frequency less than 0·001 per cent. in my material), it may be commoner elsewhere. This is suggested by the fact that a specimen of the same species was reared from only nine infested stalks collected at Grignon, Seine-et-Oise, France. In this case the parasite was collected as a young larva (6th October) and developed under observation as a primary parasite of *Cephus pygmaeus*.

The recorded hosts of *G. tricolor* are :—

Lepidoptera

Simyra albovenosa, Goeze (NOCTUIDAE) Marshall, 1874, p. 124.
Leucania sp. (NOCTUIDAE) Parfitt, 1881, p. 258.
Plusia chrysitis, Linn. (NOCTUIDAE) Billups, 1896, p. 84.
Eriogaster populi, Linn. (LASIOCAMPIDAE) Parfitt, 1881, p. 258.

Hymenoptera

Trichiosoma lucorum, Linn. (TENTHREDINIDAE) Parfitt, 1881, p. 258.

The extremely rare occurrence of the last three species, *Microcryptus unifasciatus*, *Pezomachus fallax*, and *Gambrus tricolor*, as parasites of *Cephus pygmaeus* in England, leads me to suppose that they do not maintain their population upon this host, but only occasionally or accidentally attack it. Naturally, such parasites seldom appear in studies based on small collections, but when a large amount of material is examined one or two such species almost always turn up. While these individuals are scarcely worth the consideration of the economic entomologist, to the biologist they may be of considerable significance. It may well be that they are the pioneers, the strays, the rebels, or the perverts of their species and by their non-conformance with established habits lead to the widening of the species' host relationships or even, by providing an ecological segregation, to the formation of new species.

7. Collyria calcitrator, Gravenhorst.

The genus *Collyria*, Schiødte, appears to have no close allies and is therefore of uncertain position. It has usually been placed in the PIMPLINAE (Ashmead, Schmiedeknecht, Morley), in British catalogues (Desvignes, Marshall) it has been included in the OPHIONINAE, and Cushman & Rohwer (1920) have placed it in the TRYPHONINAE. More recently, however, Cushman (1924) has replaced it in the PIMPLINAE (his ICHNEUMONINAE) and has there erected a new tribe, COLLYRIINI, for its reception. That the genus is very distinct and its relationship difficult to determine is sufficiently attested by this treatment. Only the adult insect, however, has yet been studied, and it might be expected that light would be thrown upon the matter by an examination of the larval characters. Unfortunately, this is not the case. Our present knowledge of Icheumonid larvae is very fragmentary, but it is sufficient to indicate that the larva of *Collyria calcitrator*, described below, is as peculiar as the adult.

The name *Collyria calcitrator* has been considered by Thomson (1877) to include two distinct species, to which he gave the names *trichophthalmus* and *puncticeps*. It is obvious, of course, that the name *calcitrator* would in any case have to be retained for one of these. Schmiedeknecht (1908, p. 1393) has thrown some doubt on the validity of this division, being able to recognise only one species, which he considers to be *puncticeps*, in his own material. Morley (1908, p. 263) considered *puncticeps* merely an " inconstant variety " of *calcitrator*, differing from it " in the less profuse pilosity of the eyes, in the much smoother, more shining and evenly punctate vertex around the ocelli, the narrower petiole, slightly longer terebra, and hardly clouded wings." At the British Museum there is only a single specimen attributed to *puncticeps*, a small male which Dr. Ferrière thinks does not merit separation from the typical *calcitrator*. In the course of the present study some hundreds of specimens have been examined but no differences that might warrant even varietal segregation have been observed.

Female (fig. 7) :—Length, excluding ovipositor, 6·5 to 9·0 mm. Head in front view 1·0 to 1·1 mm. high and 1·2 to 1·3 mm. wide ; in side view 0·9 to 1·0 mm. long. Vertex nearly flat ; passing abruptly into the occiput ; with strong punctures that are rather sparse laterally but almost confluent medially. Temples parallel, so that the head is as broad at the occiput as at the eyes. Occipital margin deeply concave. Vertex and cheeks margined by a low, smooth carina. Cheeks regularly punctured, the punctures a little coarser but not quite so close as on the vertex. Eyes with numerous short hairs. Ocelli arranged in a nearly equilateral triangle (fig. 8, *b*) ; the posterior ocelli about equally distant from the eyes, the occipital margin, and each other ; the anterior ocellus wholly in front of the others and about its own diameter from them. Inter-ocellar area as a whole raised, but shallowly grooved

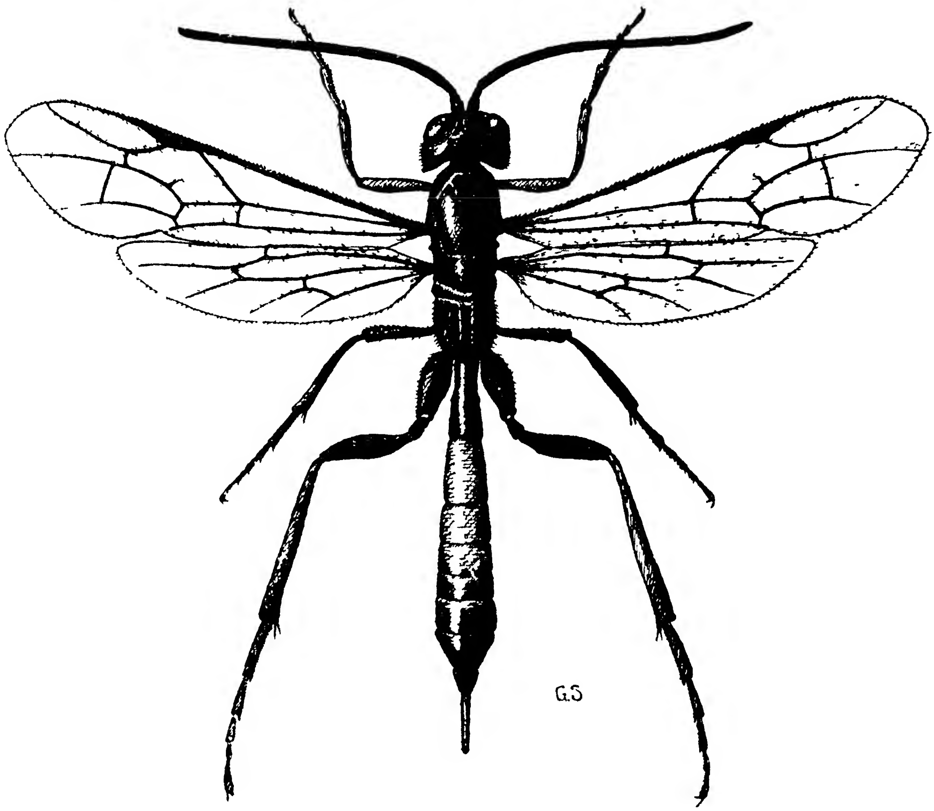

Fig 7 *Collyria calcitrator*, Grav , ♀

longitudinally ; striato-punctate Frons (fig. 9, *d*) half the width of the head ; deeply excavated above the toruli, convex just below them, then almost flat above the clypeus ; the dorsal excavation transversely ridged and raised in the middle line to a low longitudinal carina ; the ventral convex portion closely punctate, coarsely in the middle, more finely at the sides ; the orbital margins abruptly depressed, granular, indistinctly punctured. Clypeus about twice as wide as high, produced in the middle line at the apex and on each side immediately beneath the tentorial pits into three short teeth ; its surface smooth and shining with large but well-separated punctures. Oculo-malar space half as long as the clypeus is high, finely rugose. Toruli above the middle of the eyes, about three-fourths their own diameter from the eyes and the same distance apart ; lying on the bottom of the frontal

excavation so that they are presented upwards as well as forwards. Antennae with 24 to 25 segments; scape short and stout, seen in front one and one-half times as long as wide, distinctly punctured; second segment two-thirds as long as wide; third segment a mere collar; fourth and fifth segments about four times as long as wide, the succeeding segments becoming gradually shorter from three to one and one-half times as long as wide; the apical segment variable in length, about twice as long as wide at the base and rounded at the tip. Labrum (fig. 9, *a*) covered with long, straight hairs all pointing apically. Mandibles (fig. 9, *b*) stout, very strongly punctured basally, deeply notched apically to form two strong teeth of which the lower is slightly longer and broader. Stipites of the maxillae (fig. 9, *e*) heavily

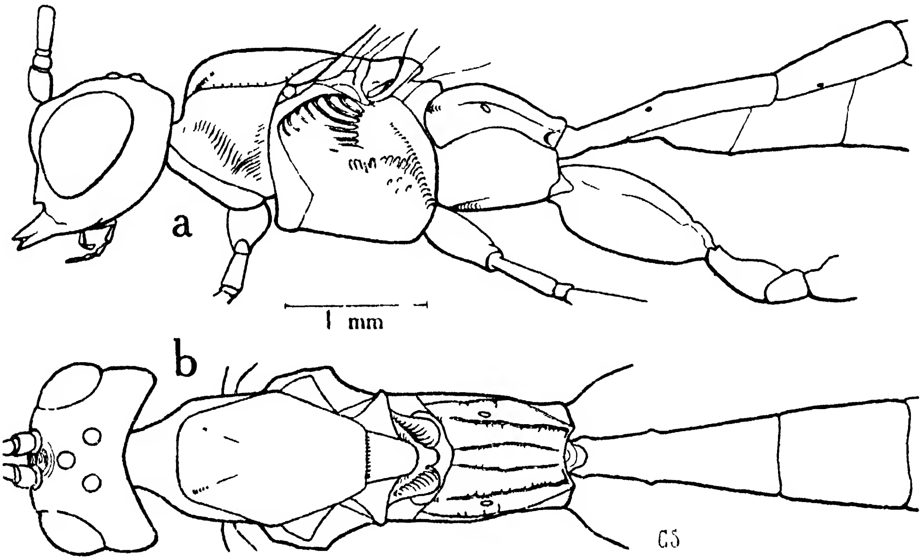

Fig. 8. *Collyria calcitrator*, Grav., head, thorax, and anterior abdominal segments of ♀. *a*, lateral view; *b*, dorsal view

chitinized and dark, the segments of the maxillary palpi 0·14, 0·18, 0·19, 0·16 and 0·19 mm. long respectively. The mentum of the labium (fig. 9, *e*) trough-like, concave dorsally, heavily sclerotized and black; paraglossae short, truncated, covered with stout setae; glossa emarginate, apically covered with short fine setae; segments of the labial palpi 0·11, 0·07, 0·09, and 0·11 mm. long respectively.

Thorax (fig. 8, *a*, *b*) elongate; 2·8 to 3·0 mm. long, 1·1 to 1·3 mm. high, and 1·0 to 1·2 mm. wide across the tegulae. Pronotal lobe flattened above, deeply excavated beneath, then raised, collar-like, just above the proepisternum; the surface of the excavation smooth and shining but traversed by several fine ridges; the remainder of the surface coarsely punctured. Proepisterna produced over the bases of the coxae, meeting in the mid-ventral line to form a low carina bordered with pits. Mesoscutum only slightly convex, the disc, indeed, rather flattened; hexagonal in outline; slightly carinate about its anterior and lateral edges; the notauli attaining half its length; the integument shining, rather closely and finely punctured. Mesoscutellum demarked anteriorly by a deep groove but maintaining the general level of the mesoscutum; its apex rounded but prominent; the sides excavated; anteriorly punctured like the mesoscutum, posterior finely rugose, the excavated sides finely striate. Metanotum short, slightly raised in the middle line below the mesoscutum but generally flat and much below the level of the mesonotum;

the concave sides shining, traversed by fine ridges. Mesepisternum rather flat and mostly covered with large, well-separated punctures, but deeply excavated and then abruptly raised to form a ridge just below the wings, the excavation strongly ridged; dorso-posterior corner flat, smooth, and shining, delimited by a series of ridges; prepectus marked off by a low carina and slightly produced ventrally to meet its fellow from the other side and form a tubercle in the median line; sterno-pleural suture absent. Mesepimeron narrow, coarsely punctured; the pleural suture a deep furrow containing pits. Mesosternum deeply grooved in the mid-ventral line, with fine parallel striae on the sides of the groove. Propodeon traversed by four low longitudinal ridges, two near the middle line, two just above the spiracles; seen from above almost square but tapering slightly posteriorly; the surfaces in general slightly convex but with a depression on each side of the spiracles and a shallow concavity behind them. Metapleura irregularly striato-punctate; separated from

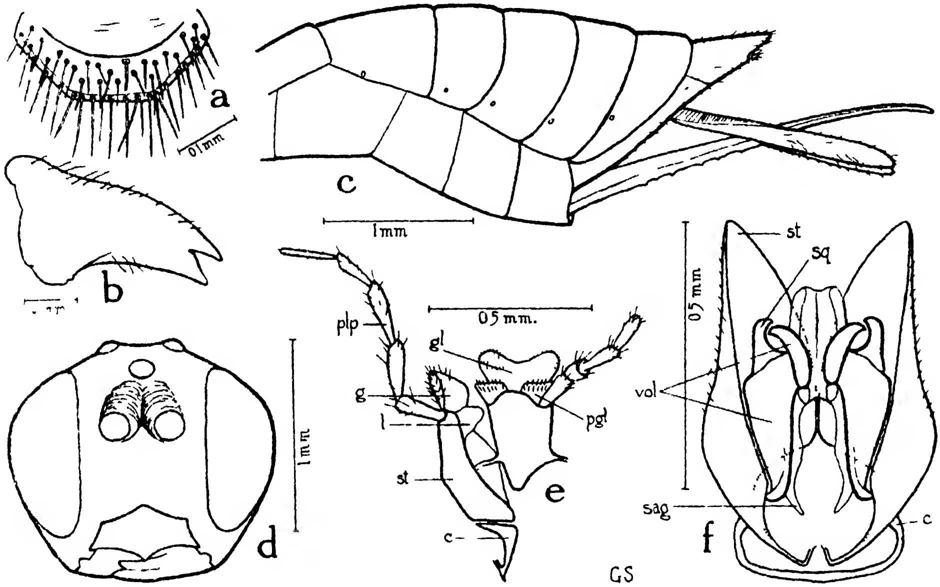

Fig. 9. *Collyria calcitrator*, Grav.: *a*, labrum, *b*, mandible, *c*, posterior abdominal segments, *d*, front view of head and *e*, maxilla and labium, of ♀; *f*, genitalia of ♂—*c*, cardo; *g*, galea; *gl*, glossa, *l*, lacinea; *pgl*, paraglossa; *plp*, palpus; *sag*, sagitta; *sq*, squama; *st*, stipes; *vol*, volsella.

the propodeon by a moderately high carina; raised to a carina anteriorly above the mesocoxa, with three or four quadrate pits just above the carina. Metasternum roughly traversely ridged.

First abdominal segment 1·4 to 1·5 mm. long and tapering from a width of 0·3 mm. at its base to 0·6 mm. at its apex; spiracles about one-third the length of the segment from the front; slightly depressed in the middle line; the surface shining with only superficial piliferous punctures. Second to eighth tergites (fig. 9, *c*) 0·9, 0·7, 0·5, 0·5. 0·4, 0·3, 0·4 mm. long respectively; gradually increasing in width from the second to the sixth which is 0·9 mm. wide; the seventh and eighth abruptly narrower; spiracles of the second and third segments about a third of the length of the segment from the anterior margin and near the lower edge; the others increasingly farther forward and higher up on their respective segments. Ovipositor exserted 2·5 mm., stout, slightly curved, irregularly serrated on its lower edge; palpi 1·5 mm. long.

The parts of the ovipositor (fig. 10, *a-d*) can be readily homologized with those of the Aculeate Hymenoptera such as the honey-bee (*cf.* Snodgrass, 1925, pp. 119–123). The morphological eighth (apparent seventh) abdominal tergite is well-developed and bears the eighth pair of abdominal spiracles. The morphological ninth tergite is composed dorsally of the conical apex of the abdomen and laterally of two broad rectangular plates, the "quadrate plates," which are separated from the dorsal arch only by an obscure suture. The tenth tergite is represented by two minute triangular sclerites attached to the apical margin of the ninth tergite, and the tenth sternite by a thinly sclerotized plate (figs. 11 and 13) underlying them. The anus opens above the tenth sternite. At the base of the quadrate plate on each side is the easily recognizable "triangular plate" from which arises the lancet of that side. The triangular plates and the lancets, according to Snodgrass, represent the eighth sternite and its gonapophyses respectively. Attached to the posterior edge of the triangular plate and

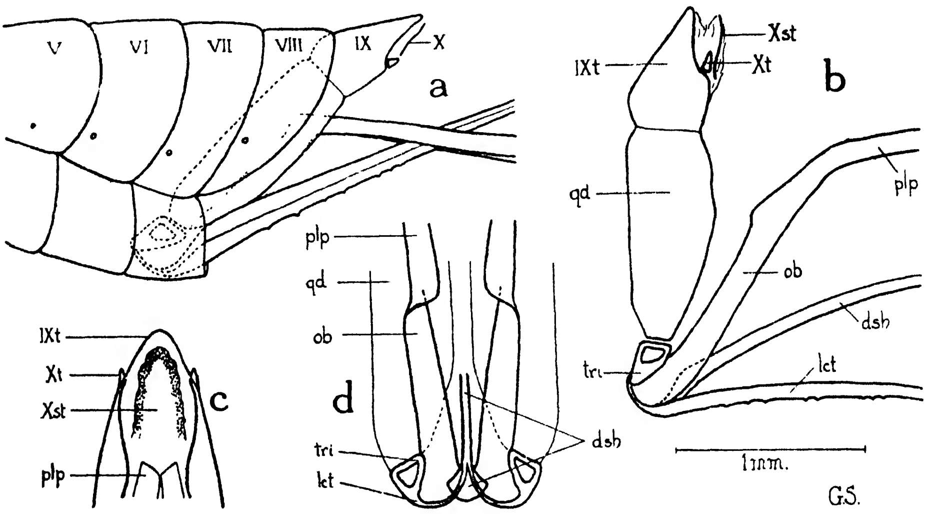

Fig. 10. *Collyria calcitrator*, Grav., ♀: *a*, end of abdomen showing plates of ovipositor *in situ*; *b*, plates of ovipositor separated; *c*, ventral view of tip of abdomen to show the tenth sternite; *d*, ventral view of base of ovipositor. —V to X, 5th to 10th abdominal segments; *t*, tergite; *st*, sternite; *dsh*, dorsal sheath; *lct*, lancet; *ob*, oblong plate; *plp*, palpus; *qd*, quadrate plate; *tri*, triangular plate.

telescoped within the quadrate plate there is on each side an elongate sclerite, the "oblong plate," that carries distally the palpus of the sting. Basally the oblong plate joins the basal expansion of the sting-sheath. According to Snodgrass, the oblong plates and the sting-sheath represent respectively the ninth sternite and its gonapophyses.

Anterior legs slender; coxa short and broad; trochanter 0·32 mm. long; second trochanter 0·11 mm.; femur 1·0 mm., rather stout; tibia 1·0 mm., slender basally, stouter apically; the single tibial spur finely pectinate within; first tarsal segment 0·65 mm., slender, grooved beneath to receive the tibial spur; remaining tarsal segments 0·33, 0·22, 0·16, 0·33 mm. long respectively; tarsal claws simple, pulvillus large. Middle legs similar; the femur 1·2 mm. long; tibia 1·6 mm., with two spurs, the inner the longer; tarsal segments 0·65, 0·37, 0·33, 0·16, 0·33 mm. long respectively. Hind coxae 1·3 mm. long, swollen, rather closely and regularly punctured; femur 1·5 mm. long, stout, closely and finely punctured; tibia 2·7 mm., slender basally, rather stout apically, the inner of its two spurs the longer; tarsal segments 0·86, 0·45, 0·37, 0·21, 0·54 mm. long respectively; hind tarsal claws strongly falcate.

Wings hyaline ; stigma slender ; areolet wanting ; nervellus reclivous, broken far above the middle ; venation as in fig. 7.

Head black ; the scape and second antennal segment black ; the flagellum black above, ferruginous beneath. Thorax entirely black. First abdominal tergite black, sometimes narrowly ferruginous at the extreme apex ; tergites 2 to 4, the base and sides of 5, and the sides of 6, reddish brown ; remainder of the tergites black except the extreme apices of tergites 4 to 8 which are very narrowly and often very obscurely lemon-yellow. All sternites except the basal half of the first yellowish ferruginous. Legs mostly black ; the anterior femora (except a broad strip beneath), the fore tibiae, the fore tarsi (except dark marks on their upper surface), the middle femora above apically, most of the middle tibiae and the middle tarsi below, the hind second trochanter, the extreme base and apex of the hind femora, the basal third of the hind tibiae, and the hind tarsi below, yellowish ferruginous.

Most of the surface with sparse, fine, short, silvery-grey hairs, which are yellowish on parts of the legs.

Male : Very similar to the female. About the same size or only slightly smaller. Sides of the abdomen nearly parallel ; first segment as in the female, apex of the second segment and the four succeeding segments about 0·8 mm. wide ; seventh and

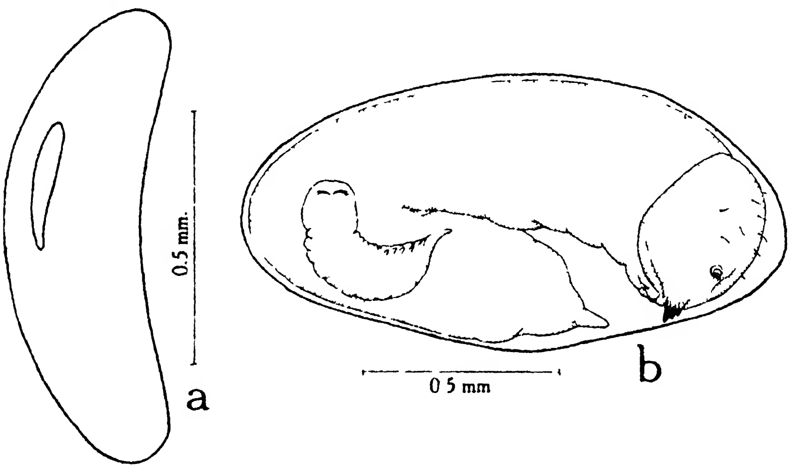

Fig. 11. *Collyria calcitrator*, Grav *a*, egg of *Cephus pygmaeus* containing egg of *C. calcitrator* ; *b*, unhatched larva of *Cephus pygmaeus* containing young larva of *C. calcitrator*.

eighth more gradually narrowed ; apex more rounded. Eighth and ninth morphological (seventh and eighth apparent) sternites well-developed ; lateral sclerite of the ninth morphological segment (the homologue of the quadrate plate of the female) subcircular ; tenth tergite and sternite as in the female. Genitalia (fig. 9, *f*) with the cardo annular, very narrow and continuous ventrally, broadened but interrupted dorsally ; stipites hard and dark, broadly pointed at the tip ; volsellae broadly attached to the stipites, weakly sclerotized, produced apically into a digitate process ; squamae falcate, apparently opposable to the processes of the volsellae ; sagittae produced anteriorly as two thin rods, fused posteriorly, and apparently ensheathing the penis. Coloration as in the female ; seventh and eighth sternites black.

The eggs of *Collyria calcitrator* are deposited within the relatively large eggs of *Cephus pygmaeus* (fig. 11, *a*). In the last week of June and during the first part of July the female parasites may be observed seeking their host in the wheat fields. Their usual procedure is to alight near the top of a stem, a few inches below the ear,

and to move downwards, head first, examining the stalk with their antennae. It is possible that they, like many other parasites, have the ability to sense their host through the tissues of the plant, but this ability would seem not to be essential, because the scar made by the ovipositing sawfly is visible even to human eyes. The parasite oviposits with its head downwards. The chorion of parasitized sawfly eggs shows clearly the marks made upon it by the ovipositor of the parasite. As many as four perforations, made prominent by the darkening of the chorion around them, have been observed in a sawfly egg in which only one parasite was found. The egg of *Collyria* is elongate fusiform, tapering more acutely at one end than at the other, and measures about 0·25 mm. in length and 0·05 mm. in thickness at the middle. It develops very rapidly, so that before the host larva has escaped from its egg, the fully-formed larva of *Collyria* can be clearly seen moving within it (fig. 11, *b*).

That *Collyria calcitrator* oviposits in the egg of its host, although its larva develops within the host larva, has already been observed by Kurdjumov (1915), who mentions that a similar habit occurs in Chalcididae (Encyrtinae) and Proctotrypidae (Platygasterinae) and has been claimed in the Braconidae (*Chelonus texanus*, Cresson) and Eulophinae (*Tetrastichus asparagi*, Crawford). The procedure is perhaps a usual one among the Chelonine Braconids, being now well known in the genus *Ascogaster*, and has recently been reported by Chrystal (1930, p. 43) in the Cynipidae (*Ibalia leucospoides*, Hochenwarth). *Collyria calcitrator* is the only Ichneumonid known to have the habit.

The first-stage larva lives free in the body cavity of the host. It has a yellowish sclerotized head with well-developed mandibles and a long tapering body with conspicuous fleshy lobes (fig. 12, *a*, *b*). The length of larvae of this type varies between 0·9 and 2·5 mm., but as the size of the head-capsule and the length of the mandibles remains the same throughout the series, I assume that all belong to the first instar and that the longer specimens are simply older. The head and thirteen body segments are clearly demarked ; the head is darkened, the body colourless. The hard head-capsule measures 0·17 to 0·19 mm. in length and 0·15 to 0·17 mm. in width. It is subquadrate in shape as seen from above, but flattened dorso-ventrally, and structurally is essentially similar to that of the second-stage larva described below. The length of the mandibles varies between 0·057 and 0·062 mm. The body of the larva is remarkable for the conspicuous dorso-lateral lobes on segments 4 to 12. These are triangular and rather small on the anterior segments, but posteriorly they become progressively longer and more digitate. The thirteenth segment bears the anal opening ventrally near its base ; posteriorly it becomes slender and curves upwards to form an apical lobe. The surface of the skin is without noticeable dermal structures. I am unable to find any trace of a tracheal system in the first-stage larva.

For its transformation from the first to the second stage, the larva of *Collyria calcitrator* apparently encysts itself. Larvae that have just transformed, whose large head-capsule is still soft and colourless and whose body is very short, are always found in a characteristic curved position (fig. 12, *c*) surrounded by a delicate membrane. I have not been able to ascertain the origin of this covering, but it is probably part of the cast cuticle of the first stage. Usually the encystment occurs in prominent evaginations of the skin of the host. These protuberances always occur latero-ventrally and may be due simply to an hypertrophy of the hypopleural swellings. As many as three or four may be found at one time on a single host, the large brown heads of the second-stage *Collyria* larvae easily to be seen within them. *Cephus* larvae bearing the sac-like swellings invariably contain the larva of *Collyria calcitrator*, but the converse is not true, for the parasite occasionally encysts between the muscle layers and the skin of the dorsum without any evagination taking place. The swellings persist through the ecdysis of the host

and are found on hibernating larvae, but in this case the parasite will have entered its third larval stage and the sac will either be empty or contain only the cast head-capsule.

The second-instar larva may be readily distinguished from the first by its much larger head-capsule and mandibles. The head-capsule measures 0·33 to 0·35 mm. in length and 0·30 to 0·32 mm. in width, while the mandibles are 0·144 to 0·148 mm. long. The head is so large that it is not surprising that for some time after transformation the body is actually smaller (fig. 12, *d*) than that of the full-grown first-stage larva. At this period, while the body is so small, the large head-capsule and

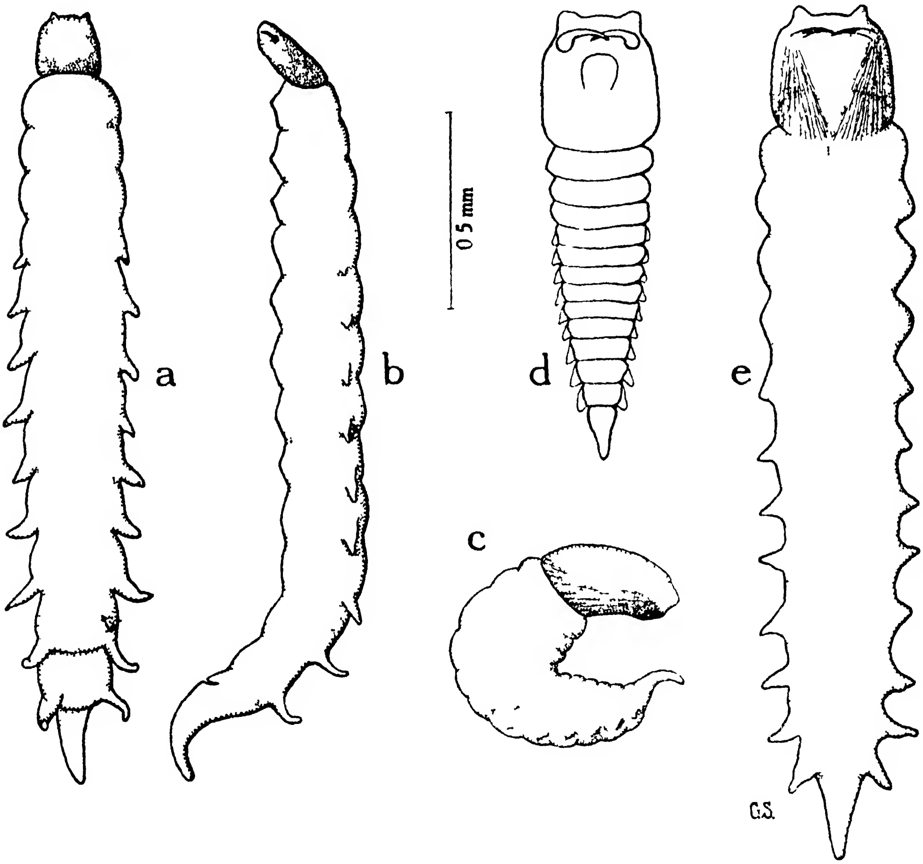

Fig 12 *Collyria calcitrator*, Grav *a* first-stage larva dorsal view *b*, first-stage larva, lateral view, *c*, second-stage larva immediately after transformation, *d*, young, and *e*, fully grown second-stage larva

the characteristic curved position give the larva a striking resemblance to the cyclopoid larvae of some Proctotrypid parasites (compare, for instance, fig. 12, *c*, with fig. 7 of Marchal, 1906). When full-grown (fig. 12, *e*) the second-stage larva is about 2·5 to 3·0 mm. long and 0·3 to 0·4 mm. wide, not much longer but considerably more bulky than the full-grown first-stage larva. The dorso-lateral lobes are still present but comparatively much shorter, and triangular rather than tentacle-like. The body is so transparent that the internal organs can easily be seen. The paired salivary glands extend backwards as far as the eighth segment. The mid-gut is capacious

but constricted posteriorly, where it connects with, but perhaps does not open into, the large globular hind-gut. The anus opens ventrally at the base of the thirteenth segment. The two malpighian tubules reach forward as far as the ninth segment. The ventral nerve cord is simple, a ganglion in each segment and paired connectives between. There is still no trace of a tracheal system.

The head (fig. 13, *a*) is the most characteristic and the most interesting part of the larva in this instar. It is subquadrate in outline; about 0·33 to 0·35 mm. in length and 0·30 to 0·32 mm. in width. The thickness decreases from 0·12 mm. in the occipital region to only 0·08 mm. at the anterior end. The hard head-capsule is largely composed of two sclerites which meet in the mid-dorsal line and form the dorsal, lateral, and part of the ventral walls of the head. These sclerites are rather widely separated ventrally, however, and a third plate, small and flat, is interposed to form the gular region. These hardened sclerites extend forward only to the region of the mandibles, the anterior extremity of the head being very soft and quite unsclerotized. The antennae, situated on the extreme anterior margin of the head, are unsegmented, dome-shaped structures, soft, colourless, and capable of considerable extension and retraction. Apically they bear a group of minute sensoria. On the anterior margin of the head, between them, is a pair of papillae which seem to be provided with a median duct. Clypeal and labral sclerites are not to be distinguished. The mandibles are 0·144 to 0·148 mm. in length, strong, falcate, and

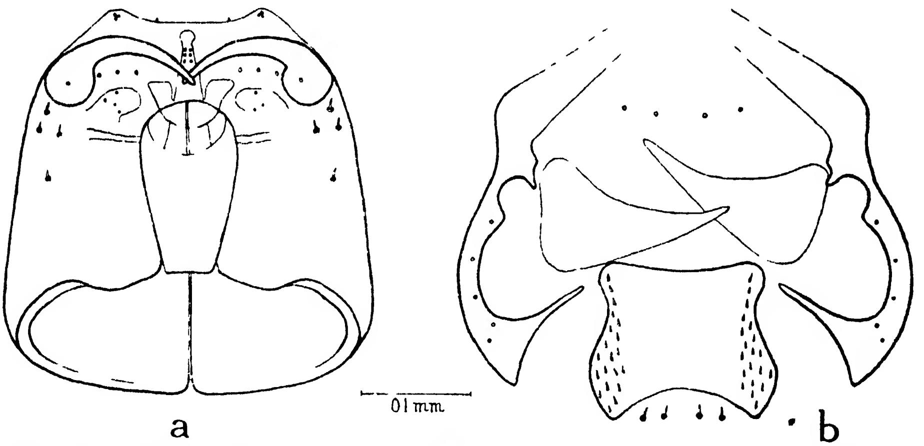

Fig. 13. *Collyria calcitrator*, Grav. *a*, head-capsule of second-stage larva from below; *b*, mouth-parts and facial rods of full-grown larva.

finely serrated on their inner edge in the middle half. The maxillae are represented by a pair of anvil-shaped fleshy lobes. The gular region, as has already been mentioned, is composed of a distinct sclerite. Anteriorly this sclerite is produced at its edge to form a strong ring while laterally it is strengthened by a pair of rods which join the main sclerites of the head-capsule and probably function with them in supporting the mandibles. Anteriorly again, the gular sclerite gives rise to a fleshy, three-lobed structure that must be considered the labium. The two lateral lobes are short, truncate at the apex, and without sensoria; the median lobe is produced forward to the anterior margin of the head and bears six sensoria arranged in three pairs. The surface of the head-capsule is finely coriaceous. There are a few sensoria, in particular a curved row of four on each side ventrally near the anterior margin and four small setae at the base of the mandibles, three arranged in a triangle, the fourth behind. The greater part of the head-capsule is occupied by the enormous muscles that operate the mandibles.

The third-stage larva (fig. 14, *a*) is very different from the first and second stages, being extremely flaccid and without any darkened sclerotic parts. It is 3·0 to 3·5 mm. long. The head and thirteen body segments are clearly demarked, but the head is not at all darkened or hardened, is without any noticeable facial rods, and appears to lack even mandibles. Of the lobes so conspicuous on the body of the first and second stages there remain only vestiges on the posterior segments. The integument is very delicate and there are no prominent dermal structures.

It is difficult to ascertain the number of ecdyses when the cast skins are so delicate, but I think that one occurs late in the autumn and that the larva dissected from the host in the winter (fig. 14, *b*) is the fourth stage. It then measures 5·0 to 5·5 mm. in length, 1·25 to 1·5 mm. in width, and about 0·8 mm. in thickness. Again the larva is without any darkened sclerotic parts and is extremely flaccid. The lobes on the body have now entirely disappeared and the apical segment has become short and broad. The larva is now white, but the contents of the gut give it a dull greenish appearance. The tracheal system is not at first apparent but attains some development later in this stage.

Early in the spring the *Collyria* larva increases rapidly in size. An ecdysis is passed and in May the larva becomes full-grown (fig. 14, *c*). It is then cylindrical and firm, having lost its earlier flattened shape and flaccidity. It measures 9 to 11 mm. long and about 1·5 mm. in thickness, and is creamy white in colour. The head and thirteen body segments are clearly distinguishable. The head, like the rest of the body, is extremely delicate and without any sclerotized areas. There are fleshy lobes about the mouth-opening which probably represent the labral, maxillary, and labial areas, but there are no hardened or darkened parts at all. Careful staining, however, shows that the mandibles and some of the usual facial rods are represented but not well developed (fig. 13, *b*). A large plate underlies the labial area, the mandibular struts may be clearly distinguished, and there are vague sclerotic areas in the labral region, but all the parts are so poorly represented that it is difficult to homologize them. The mandibles, usually well-developed when all other structures fail, are to be made out only with difficulty. The three thoracic segments at this stage are slightly wider than the abdominal segments. The thirteenth segment is depressed about the anal opening, so as to have a lobed appearance in profile. There are no conspicuous dermal structures but around the middle of each segment there is a broad band of closely set, minute papillae, readily visible only when the skin has been cleaned and stained.

The respiratory system (fig. 14, *d*, *e*) is fully developed in the last-stage larva. The lateral tracheal trunks are joined by an anterior commissure in the first segment but are otherwise unconnected, there being neither ventral nor posterior commissures. The lateral accessory trunks usually present in the second and third thoracic segments of Ichneumonid larvae are also wanting. Ten pairs of stigmatic trunks leave the lateral trunks in the anterior part of segments 2 to 11 inclusive, and lead to ten pairs of spiracles situated near the anterior margins of the same segments. Two pairs of tracheae leave the lateral trunks in the first segment and pass forward into the head, proliferating abundantly. There are eleven pairs of dorsal and an equal number of ventral tracheae. The dorsal tracheae normally leave the lateral trunks a little before, the ventral tracheae a little behind, the stigmatic trunks in segments 3 to 11 and in the same relative position in segment twelve, where there is no stigmatic trunk. In segment two both the dorsal and the ventral tracheae arise behind the stigmatic trunk. The ventral tracheae of segments 2 to 4 divide into two principal branches immediately after leaving the lateral trunks; or occasionally, as an abnormality, the two branches arise independently but adjacently from the lateral trunks. The other eight pairs of ventral tracheae do not form two principal branches but simply give off small branches and tracheae along their length. The ventral tracheae from opposite sides, it is to be repeated, do not meet and join. The

respiratory system seems to be unconnected with the outside until immediately before pupation and even then I have never found air in the distal part of the second pair of stigmatic trunks—it may be that this pair of spiracles, which are slightly reduced, is non-functional.

It will be observed that in several respects the larval stages of *Collyria calcitrator* are highly interesting. Considering first the tracheal system, it is immediately noticeable that this larva lacks the accessory longitudinal tracheal commissure that has been considered (Seurat, 1899, p. 96; Thompson, 1930, p. 22) so characteristic of Ichneumonid larvae, and would therefore run in Thompson's key to the BRACONIDAE.

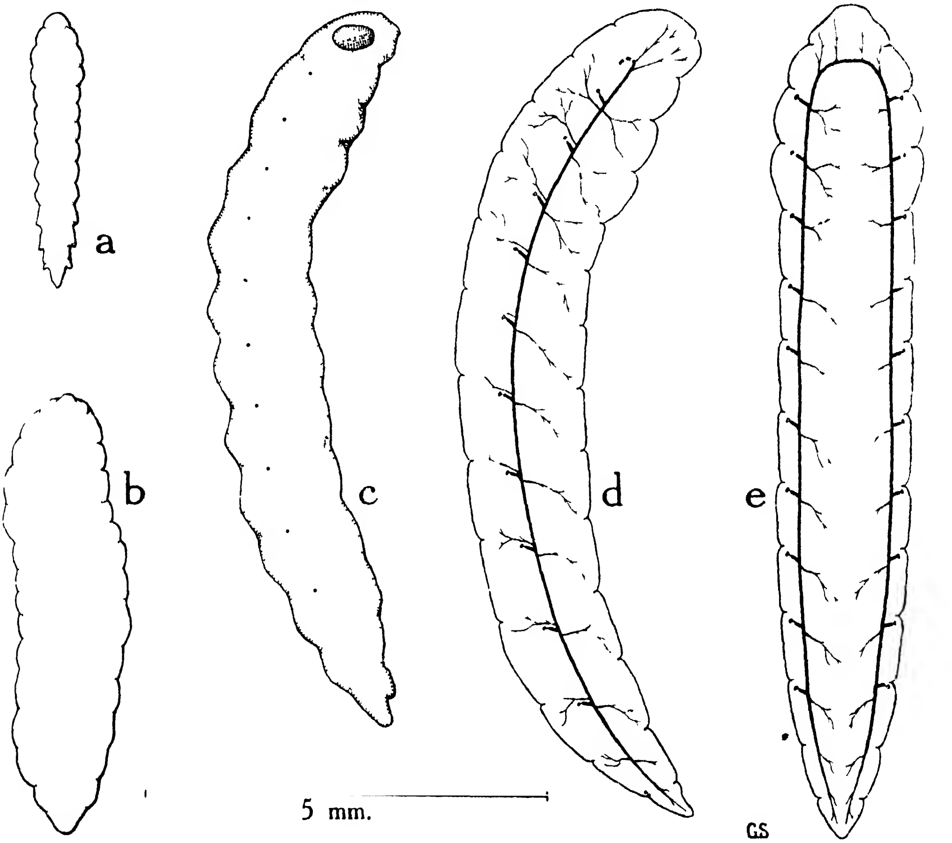

Fig. 14 *Collyria calcitrator*, Grav. *a*, third-stage larva; *b*, fourth-stage larva; *c*, full-grown larva; *d*, lateral, and *e*, ventral view of tracheal system of full-grown larva.

The lack of a posterior commissure uniting the two tracheal trunks is also remarkable. In possessing ten pairs of spiracles the larva agrees with that of *Pimpla pomorum* (Imms, 1918) and *P. detrita* (see below) and differs from all other described Ichneumonid larvae, in which only nine pairs have been distinguished. Here, however, the spiracles occur in a regular manner near the anterior margins of segments 2 to 11, while in the other cases the anterior pair of spiracles is situated near the posterior margin of segment one. The almost unsclerotized state of the mouth-parts and facial rods of the full-grown *Collyria* larva is sufficiently unusual to be worthy of mention. Finally, the heavily sclerotized head-capsule of the first two larval stages is to be especially noted. This character, again, is one that is usual in the BRACONIDAE

and has not yet been reported in any Pimpline Ichneumonid. In the Ophionines first-stage larvae with a hard head-capsule have been described (Cushman, 1916, in *Thersilochus conotracheli*, Riley; and Tothill, 1922, in *Therion morio*, Fabricius), but here the capsule seems to be structurally very different. It may well be, however, that in this character *Collyria* reveals some relationship with the TRYPHONINAE, for some unpublished drawings by Dr. Kamal of first-stage larvae of *Syrphoctonus*, *Homotropus*, and *Diplazon* show a very similar head.

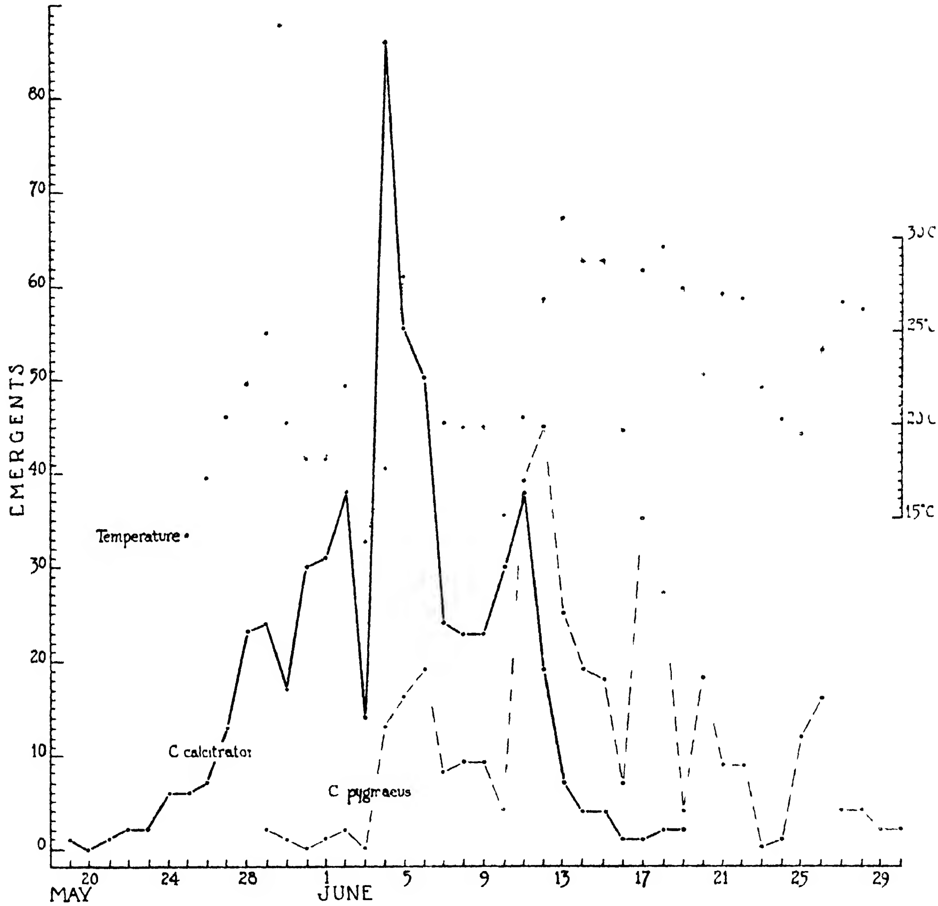

Fig 15 Graph showing emergence of *Collyria calcitrator* in relation to its host, *Cephus pygmaeus*, and to the temperature The temperature is the average of twelve two-hourly readings of the thermograph

When the larva has eaten all the internal tissues of its host, it lies swathed in the empty skin which finally bursts and is pushed out of the way to the end of the hibernaculum. It spins no cocoon of its own, being within that already constructed by the *Cephus* larva. A circular area becomes dark on each side of the head-region, marking the eyes of the pupa developing within. During May the parasite pupates and in June the adult insect gnaws its way through the plug at the end of the stubble and escapes into the open air.

To show the emergence of *Collyria calcitrator* in relation to that of its host and to the temperature, one thousand stubs retained from those collected for shipment to Canada were kept in an unheated insectary and the emergents removed and noted daily. A thermograph stood beside the emergence cage. The graph (fig. 15) shows clearly :—(1) that the parasite emerged about a week before its host ; and (2) that the emergence of both *Collyria* and *Cephus* was rather closely correlated with the temperature. Subsequent observations indicated that the actual dates of emergence shown on the graph are about two weeks early as compared with the dates of natural emergence in the field. Presumably the temperature in the insectary had been higher than the ground temperature outside. There is, of course, only one brood a year.

From this same material 259 males and 327 females of *Collyria calcitrator* emerged, or 44·2 males and 55·8 females per 100 emergents. In general the emergence of males preceded that of the females by about five days although the greatest single emergence of both sexes occurred on the same day.

The adults visit the umbels of *Heracleum* and on one occasion a male was observed feeding on a flower of wheat. Mating occurs on the heads of *Heracleum*. The flight of both sexes is steady and rather slow with the long hind legs trailing down and backwards. In the open, specimens on the wing can be followed with fair ease, but among the swaying stalks of grain it is impossible to keep an individual in sight for very long. Settled, the movements of the parasite are slow and ungainly. It is alert but its long legs seem to prevent it from moving very quickly. The insect is active throughout the day and feeds even in quite dull weather, but oviposition was observed only in the early afternoons of bright warm days. On 3rd July, specimens were observed feeding as late as 9.00 p.m., but by 9.30 p.m. all were resting, head downwards, on the stems of wheat, in which position, probably, the night is passed.

Collyria calcitrator is very widely distributed in the Palaearctic Region having been reported from Sweden, Thuringen, and England in the north and west, to Kharkov, Stavropol, and Tiflis in the south and east. Within this range only two hosts have been reported, *Cephus pygmaeus*, Linn., and *Trachelus tabidus*, Fabr., both CEPHIDAE feeding in the stems of cereals, especially wheat. A third host is added by Mr. Smith's account (this journal, p. 549) of the successful parasitism of *Cephus cinctus*, Norton, by the specimens liberated in Western Canada.

Collyria calcitrator is by far the commonest parasite of *Cephus pygmaeus* in England. Dissections of 5,015 overwintering *Cephus* larvae show a parasitism of 71·13 per cent., but as these hibernating larvae are only 87·51 per cent. of the total population, the effective parasitism by *Collyria calcitrator* is 62·25 per cent. of the sawfly population.

No hyperparasites of *Collyria calcitrator* have been discovered, but the species has, of course, in some cases, to compete with the other primary parasites of its host. Three of the primary ectophagous parasites of *Cephus*, *Hemiteles hemipterus*, *Leptocryptus bellulus*, and *Microbracon terebella*, are definitely intrinsically superior (H. S. Smith, 1929) to *Collyria* for I have found the head-capsule of first- and second-stage *Collyria* larvae among the remains of the hosts of these three species. *Pimpla detrita* is almost certainly also intrinsically superior but it so scatters the remains of its host that *Collyria* remains among them would be difficult to find. The only other endophagous parasite, *Pleurotropis benefica*, is intrinsically inferior to *Collyria* as demonstrated in the notes under that species.

The enormous mandibles of the first- and second-stage larvae of *Collyria* are chiefly used against their own kind. It often happens that more than one egg of the parasite is laid in a single *Cephus* and in this case, since only one *Collyria* can develop in each host, all but one must die. The elimination of the others usually takes place in the first and second larval stages, particularly the second, while the

larvae are furnished with their powerful mandibles. Two second-stage larvae placed together in a drop of the haemolymph of the host will attempt to grasp each other at once. One very seldom finds a host containing two living third-stage larvae, and where a second-stage and a third-stage larva occur together, as occasionally happens, the third-stage larva invariably succumbs to the attack of the younger parasite. I hope to publish elsewhere some notes on superparasitism in this species.

The value of *Collyria calcitrator* as a parasite of *Cephus pygmaeus* is discussed in detail in the fourth part of this paper (p. 541), where the natural control of the pest is described. Here it is sufficient to state that in my opinion this species is the most important controlling agent of the wheat-stem sawfly in England.

8. **Pimpla detrita,** Holmgren.

There has been some difficulty in the determination of this species. It was originally given the name *Pimpla detrita*, Holmgren, by Dr. Ferrière. Later, having regard to the first abdominal segment of the males, he thought the species should be called *brunnea*, Brischke. Only some of the conspecific females, however, seemed to be *brunnea*; others agreed with *detrita*. His final conclusion was that there might be two different species present (*detrita* and *brunnea*) but with doubt. Specimens of both sexes sent to Dr. A. Roman, of the Naturhistoriska Riksmuseum, Stockholm, were returned labelled *Epiurus detritus*, Holmgren, but in his letter Dr. Roman says, " I have retained a pair of the *Epiurus* because there was some uncertainty about the ♂." Of the two names available, *detrita* and *brunnea*, I use the former; first, because most of the evidence favours it and, secondly, because Thompson (1930, p. 101), Thorpe* (1930, p. 400), and Smith (1931, p. 154), have already published my record under that name. I trust that when future research clears up this taxonomic difficulty my description will be found sufficiently complete to indicate which form I have before me.

Female : Length, excluding ovipositor, 5·5 to 8·0 mm. Head in front view (fig. 17, *a*) a little wider than high; seen from above, widest across the eyes, the temples receding, the occipital margin deeply concave and wider than the mesoscutum. Vertex declivous behind the posterior ocelli, its posterior aspect medially concave. Posterior ocelli about as far apart as from the eyes but less than half that distance from the edge of the vertex. Interocellar area raised but with a median furrow. Eyes naked. Frons above the toruli shallowly concave, immediately below them transversely raised, lower still flat with a slight median swelling. Frons, vertex, and cheeks smooth and shining, with sparse, superficial, piliferous punctures. Clypeus flat, twice as wide as high, about a quarter its width from the eyes; its apical margin strongly bilobed; its surface with only a few fine punctures; its extreme apical margin with a close row of hairs. Oculo-malar space as long as the clypeus is high, posteriorly smooth and shining, anteriorly coriaceous. Toruli only slightly above the middle of the eyes, about one-third their diameter from the eyes and one-half their diameter apart. Antennae of 24 to 25 segments; scape swollen, punctured, hairy; flagellar segments slender, densely covered with short hairs, gradually becoming shorter from 5 times to about 1·5 times as long as wide. Labrum extending only slightly beyond the lobes of the clypeus; its apical margin rounded and bearing a group of short hairs. Mandibles very short, little longer than wide at the base, the truncate apex notched to form two teeth; the lower slightly larger and obliquely truncate, the upper rounded apically. Segments of maxillary palpi 0·13, 0·13, 0·16, 0·10, 0·16 mm. long respectively, the second segment much swollen; of the labial palpi 0·10, 0·08, 0·06, 0·10 mm. long respectively.

* Thorpe's single male from *Rhyacionia buoliana* was also determined as *P. detrita* but is not conspecific with my specimens, differing, among other things, in the stronger curvature of the fore tibiae and in the shorter abdominal segments.

Thorax (fig. 16) a little higher than wide and twice as long as wide. Pronotal lobe smooth and shining, largely impunctate but with a few punctures dorsally and a series of obscure ridges just before the lateral margin, which is abruptly raised. Proepisternum sparsely punctured. Mesoscutum convex anteriorly, flattened posteriorly; the disc depressed; notauli present but not well developed, not reaching the middle of the segment; parapsidal furrows absent; the surface smooth and shining, with sparse superficial piliferous punctures; the depressed area in front of the scutellum without ridges or pits. Mesoscutellum raised, punctured like the mesoscutum. Metanotum depressed laterally, raised narrowly in the middle line. Mesepisternum in general convex but grooved dorsally to form a short rounded ridge below the tegula and abruptly concave posteriorly about the spiracles; prepectal suture represented by a low carina; sterno-pleural suture absent. Mesepimeron long and narrow, the mesopleural suture a deep furrow with small pits in the bottom. Surface of the whole mesopleura smooth and shining with only sparse piliferous punctures, the concavity of the mesepimeron impunctate. Metapleura very constricted

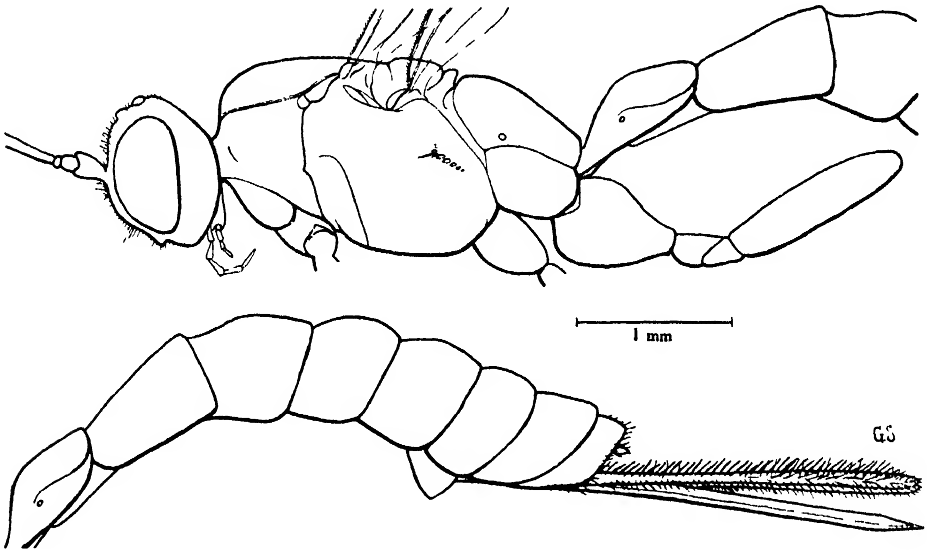

Fig. 16. *Pimpla detrita*, Hlgr., side view of ♀.

dorsally; the broad ventral plate convex, punctured like the mesopleura. Propodeon with two median ridges well developed anteriorly and two lateral ridges well developed posteriorly, but without any transverse carinae; smooth and shining, medially obscurely punctured, laterally coarsely but still superficially striato-punctate; the spiracles small and round.

First abdominal tergite only slightly longer than wide; anteriorly with a broad, almost impunctate, median area bounded on each side by a low carina; the extreme posterior margin also impunctate; elsewhere coarsely, irregularly punctate or rugose; spiracles small, about the middle of the segment. Second tergite slightly, third to seventh tergites much, wider than long; all closely covered with large round punctures, deep on segments 2 to 5, superficial on segments 6 and 7; the apical margin of each tergite impunctate. Eighth tergite impunctate basally, with a few piliferous punctures apically. Ovipositor as normally held apparently half as long as the abdomen, when fully exserted quite two-thirds as long as the abdomen; straight, sharply pointed at the tip; the lancets with eight ridges giving the appearance of

eight overlapping scales (fig. 17, *b*). Palpi reaching the tip of the ovipositor, densely hairy. Plates of ovipositor as in fig. 17, *g*.

All the femora somewhat swollen ; fore tibiae slightly curved basally ; last segment of hind tarsi about three times as long as the preceding segment ; tarsal claws with a broad basal lobe (fig. 17, *f*).

Wings hyaline, not at all infuscate ; tegulae, axillary sclerites, and extreme bases of wings, yellow ; wing veins generally dark but with a tendency to become

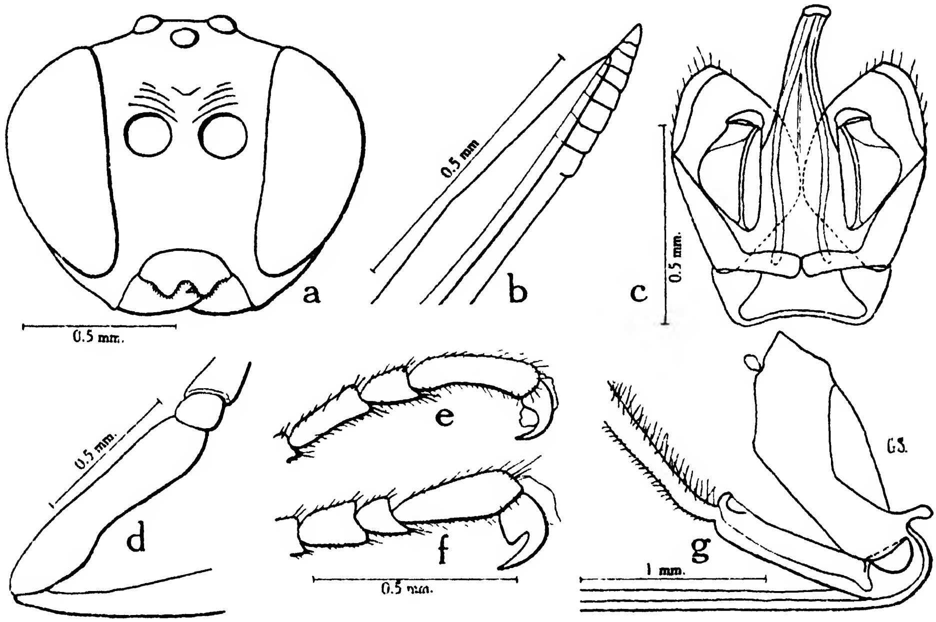

Fig. 17. *Pimpla detrita*, Hlgr. : *a*, front view of head of ♀ ; *b*, tip of ovipositor ; *c*, genitalia of ♂ ; *d*, fore femur and base of tibia of ♂ ; *e*, tarsal segments and tarsal claw of ♂ and *f*, of ♀ ; *g*, plates of ovipositor.

lighter, especially apically ; stigma mostly dark but amber-coloured at its base and apex ; nervellus perpendicular or slightly reclivous, broken either slightly or considerably below the middle.

Head, thorax, and abdomen entirely black. Flagellum of antennae brown to yellowish beneath and apically. Legs almost entirely reddish brown but the fore coxae, the base and apex of the posterior tibiae, the apices of the posterior tarsi, and the pulvilli and claws of all legs, dark.

Pubescence short, sparse, silvery white ; a few long hairs on the clypeus ; the palpi of the ovipositor densely covered with long dark hairs.

Male : Differs from the female as follows : Smaller (dwarf specimens being only 4 mm. long) and very slender. Frons less swollen in the middle below the toruli. Thorax less than half as wide as long. First abdominal tergite 1·5 times as long as wide ; the ridges bounding the median area higher and extending posteriorly to the base of a rounded swelling on the posterior margin ; the sides of the tergite outside the ridges concave ; spiracles slightly before the middle ; all except the apical swelling and the basal part of the median area rugose. Second to fourth tergites longer than wide, fifth to seventh about square ; second tergite with a large impunctate depression on each side basally ; apical margins of all tergites impunctate,

elsewhere very closely punctured, deeply on the anterior segments, more superficially on the posterior segments. Genitalia as in fig. 17, *c* ; the penis curved downwards. Legs more slender ; the femora not swollen , the fore femora emarginate beneath (fig. 17, *d*) ; tarsal claws simple, not basally lobate (fig. 17, *e*). Underside of flagellum yellowish. All coxae black but the fore coxae sometimes slightly yellowish beneath. Dark markings on posterior tibiae and tarsi more accentuated.

The confusion between this species and *P. graminellae*, Grav., was formerly very great, but Schmiedeknecht (1906, p. 1082) has clearly distinguished the two, applying the name *detrita* to the species having the nervellus broken at or below the middle and the fore femora of the male emarginate beneath, *holmgreni* (his name for *graminellae* of authors) to that having the nervellus broken far above the middle. Morley

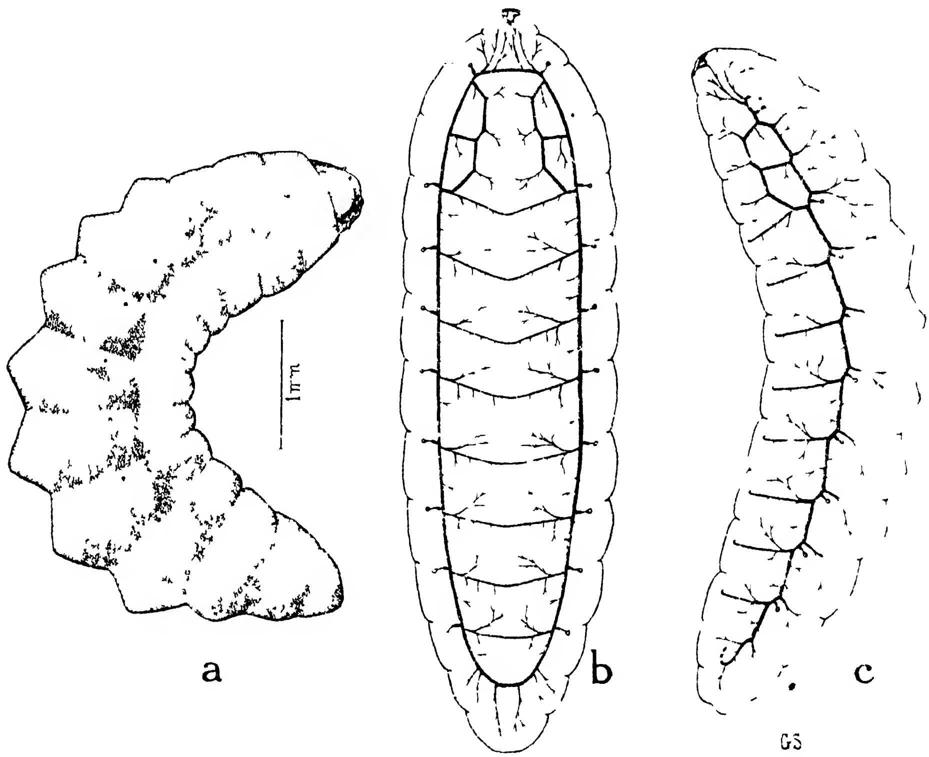

Fig 18 *Pimpla detrita*, Hlgr *a* full-grown larva , *b*, ventral, and *c*, lateral view of tracheal system of full-grown larva

(1908, p. 87) insists that in *P. detrita* the nervellus is intercepted exactly in the centre and discards Schmiedeknecht's male and Brischke's two host records because in these parasites the nervellus was broken below the middle. His objection cannot stand. Among over two hundred specimens reared from *Cephus pygmaeus* that I have examined in the course of the present study, I find the nervellus usually broken slightly below the middle, though sometimes exactly at the middle and often considerably below it. I have never found the nervellus in *P. detrita* intercepted above the middle.

Oviposition of this species was observed in the field on several occasions between 16th and 25th July, 1930. The egg is laid externally on the *Cephus* larva which is first paralysed. There are five larval stages all of which are ectophagous. The

head-capsule of the first-stage larva is amber-coloured and more sclerotized than in the later stages, though far less so than in the corresponding stage of *Collyria calcitrator*. It is of the usual rounded shape with slender antennal organs 0·06 mm. long. The mandibles are about 0·09 mm. long, slightly curved, and without serrations. The head-capsule of the second to fourth larval stages is distinctly harder than the cuticle of the body but is uncoloured. In these three stages the antennal organs are comparatively smaller than in the first stage and the mandibles are finely serrated below near the tip. Development is rapid and the larva is full-grown about the middle of August.

The full-grown larva is yellowish white with brown mandibles and facial rods. It is firm in texture and opaque. In outline it is elongate fusiform, and when in an extended position measures 6·2 to 6·8 mm in length, 1·5 to 1·8 mm. in maximum

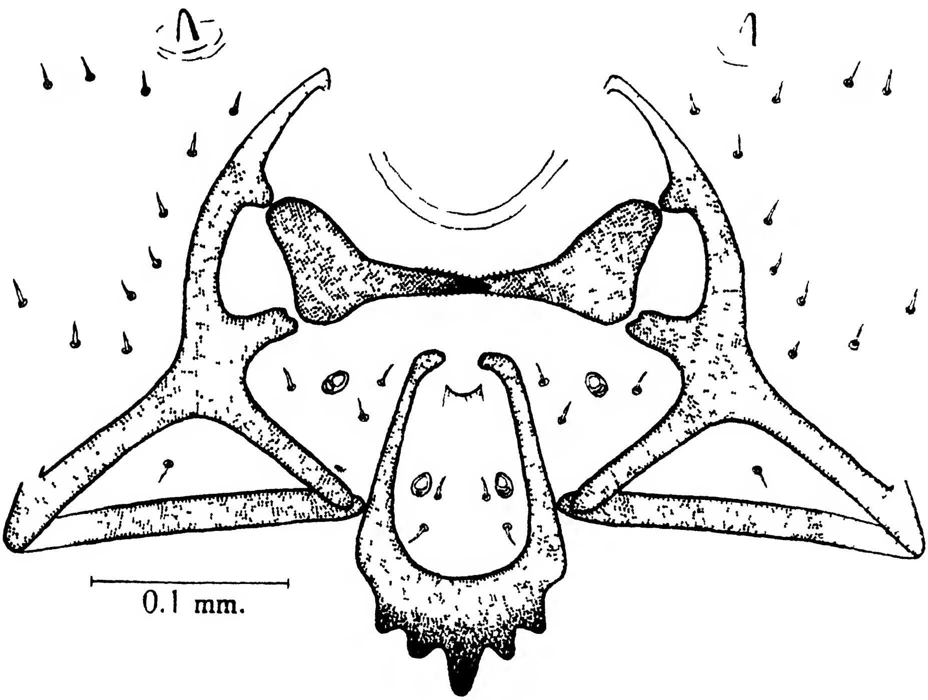

Fig 19 *Pimpla detrita*, Hlgr , facial rods, mouth-parts, and facial setae of full-grown larva

width, and 1·1 to 1·4 mm. in thickness At rest, however, the larva invariably lies on its side curved in a semicircle (fig. 18, *a*) and in this position measures 3·6 to 4·0 mm. from the head to the anal segment. The larva is divided by distinct constrictions into a head and thirteen segments. The segments are all more convex dorsally than ventrally and segments 4 to 10 bear prominent transverse dorsal humps. The anal segment is deeply transversely grooved on its posterior aspect, the dorsal lobe thus formed slightly over-reaching the ventral. For the most part the cuticle is smooth, shining, and translucent, but on parts of the dorsum and especially on the hypopleural swellings there are low papillae which, under the high power, appear simply as poorly defined circular areas about their own diameter apart. On part of the dorsum, notably just anterior and dorsal to the spiracles, there are areas of a peculiar cuticular process ; a transversely elongate papilla bearing three to five minute teeth on its

crest (fig. 20, *d*). In a circular area about each spiracle there are curved sclerotic lines forming a rosette (fig. 20, *e*) with the opening of the spiracle in the centre. Each segment bears fourteen setae arranged in a single transverse row a little behind the middle. On each side one seta is found on the median dorsal hump, two setae between the dorsal hump and the hypopleural swellings, two on those swellings, and two below them on the ventral surface (fig. 20, *f*).

The head is large and well differentiated. Its cuticle is smooth and much harder than that of the body segments. Dorsally there are two pairs of longitudinal sclerotic areas, the inner pair nearer the median line broad and dark, the outer pair narrow and sometimes so pale as to be scarcely visible. The antennal organs (fig. 20, *c*) consist of a cone-shaped segment 0·034 mm. high surmounting a circular swollen area about

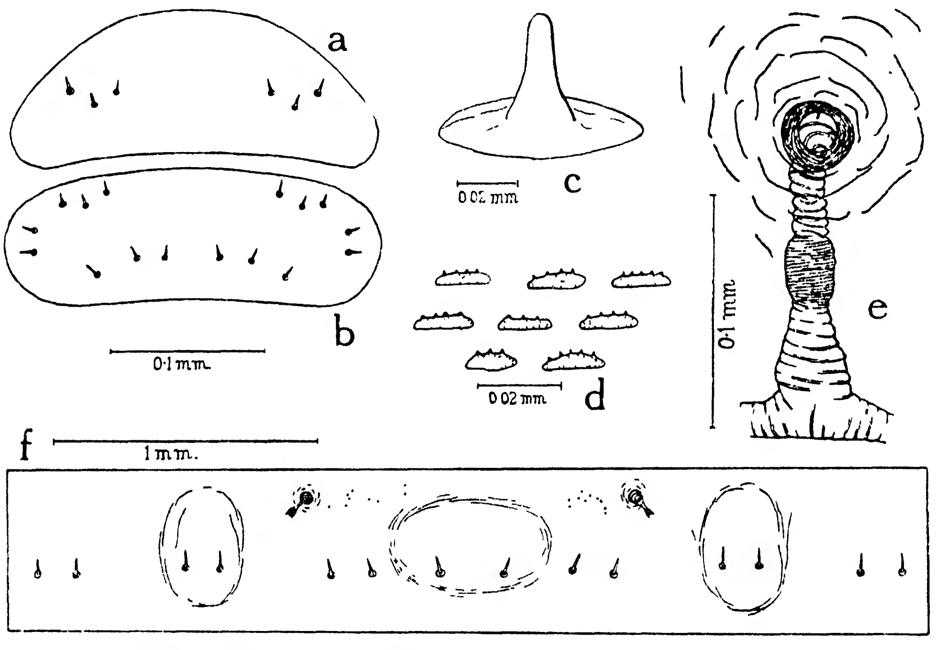

Fig. 20. *Pimpla detrita*, Hlgr., full-grown larva: *a*, clypeal area; *b*, labral area; *c*, antenna; *d*, cuticular processes on the dorsum; *e*, spiracle; *f*, setal map of fifth segment.

0·07 mm. across. There is a distinct clypeal area, sclerotic and suffused with brown, slightly convex, curved dorsally but rather truncate apically, bearing three setae on each side (fig. 20, *a*). The labrum, below it, is soft and colourless and bears eight setae on each side, three dorsally, three forming an apical row, and two near the extreme sides (fig. 20, *b*). The mandibles are conical in general form—a slender cylindrical apex, very hard and dark, upon a broad circular base lighter in colour. The slender apical shaft of the mandibles is finely toothed both dorsally and ventrally a short distance from the apex. The maxillary areas are poorly differentiated; each bears three setae and a low tubercle on an 8-shaped sclerotic base. The labial area also bears a pair of tubercles on sclerotic bases like those of the maxillary areas, as well as two pairs of setae and the spinneret. The dorsal part of the labium is very moveable, being capable of inflation so that it bulges in front of the head, or withdrawal so that the opening of the salivary duct is within the buccal cavity and immediately beneath the mandibles. Setae occur in other parts of the face as illustrated (fig. 19).

The facial rods of this larva (fig. 19) are interesting because one of them, the prominently dentate labial ring, is clearly external in its apical part. When the dorsal part of the labium, bearing the opening of the salivary duct, is drawn into the mouth, the apex of the labial ring is thrust out ; when the dorsal part is protruded, the apex swings in and becomes appressed to the skin in the gular region. The essential arrangement of the other parts is the same as that found in the larva of *Hemiteles hemipterus* described above and is shown in fig. 19. Most of the parts are thick and dark but the frontal struts are poorly developed above their mandibular articulation and form no frontal arch. At its outer end the labial strut joins the mandibular strut ; at its inner end it is fused with the maxillary strut. The angle of the fused maxillary and labial struts supports the labial ring and forms the fulcrum on which it swings. Internally both the anterior and the posterior arms of the tentorium are incomplete ; the cuticle of the head and the superficial facial rods are so strong that internal support is perhaps unnecessary.

Ten pairs of spiracles are present but one pair is vestigial. The first pair opens near the posterior margin of the first segment and is well developed. The second pair is extremely small and is situated on the second segment very near its posterior margin. This pair is non-functional, being unconnected with the tracheal trunks. The third to tenth pairs of spiracles open near the anterior margins of segments 4 to 11. The lateral tracheal trunks (fig. 18, *b*, *c*) are connected by an anterior and a posterior commissure in the first and twelfth segments respectively. Lateral commissures are present in the second and third segments. The dorsal tracheae leave the lateral trunks in front of the spiracles, proceed dorsally a short distance, and then divide into two principal branches which ramify throughout the dorsal part of the segment. The ventral tracheae leave the lateral trunks a little behind the spiracles and also divide into two principal branches. The anterior of these ramifies throughout the anterior part of its own and the posterior part of the preceding segment. The posterior branch, however, gives off only one branch of moderate size and a few fine tracheoles, and passes directly and undiminished to the mid-ventral line where it meets and connects with its fellow from the other side. There are thus formed eight ventral commissures in segments 4 to 11.

No real cocoon is spun by the larva of *P. detrita* though it can, on occasion, produce a few strands of coarse brownish silk. It lies during the winter among the brown particles of frass in the lumen of the stalk with the few hard fragments of the destroyed sawfly larva about it. Since the host larva is paralysed early in the season before it has descended to the base of the stem and since the parasite larva does not move away when its meal is finished but simply replaces its host in the original position, the *Pimpla* larva is found quite high in the stalk, usually above the second node from the ground. As has been pointed out above (p. 492) this habit leads to the destruction of a large proportion of its own population, for many larvae lying too high in the stem are cut off, removed, and destroyed with the straw. In the experiment described, which was planned for another purpose and unfortunately deals with only five larvae of *P. detrita*, 60 per cent. of the parasites were thus lost.

The emergence of *Pimpla detrita* from wheat stubble in insectaries began in 1930 on 5th May, fully three weeks before the emergence of *Cephus pygmaeus* from the same stubble. The males preceded the females by about a week. Of 353 emergents, 117 were males and 236 were females ; a sex ratio of 33·1 males and 66·9 females per 100 individuals. Emergence continued for 33 days, until 6th June. These dates, however, are about two weeks early owing to the storage of the stubble in insectaries during the winter. When correction is made for this we have *P. detrita* emerging in 1930 between 19th May and 20th June. Oviposition of this species was first observed in the field on 16th July and could not have begun, unobserved, much earlier because even then the majority of the sawfly larvae were too small to be entirely suitable for parasitization. What the adult parasites do between their emergence in May and

June and the middle of July, when they oviposit, is unknown. It seems unlikely that there is time between these dates for a complete second generation on an alternate host, but it is possible that the earlier emergents, finding the *Cephus* larvae not far enough advanced for their purpose, turn their attention to another insect.

The host list of *Pimpla detrita* includes the following insects :—

Lepidoptera—
Chilo phragmitellus, Hübn. (PYRALIDAE). Bignell, 1898, p. 501.
Tortrix viridana, Linn. (TORTRICIDAE). Santos Hall, 1924, p. 34.
Evetria buoliana, Schiff. (EUCOSMIDAE). Tempel, 1925, p. 167.
Polychrosis botrana, Schiff. (EUCOSMIDAE). Catoni, 1914, p. 250.
Argyroploce variegana, Hübn. (EUCOSMIDAE). Ozols, 1928, p. 145.
Aegeria formiciformis, Esp. (AEGERIIDAE). Brischke, 1880, p. 112.

Coleoptera—
Anthonomus pomorum, Linn. (CURCULIONIDAE). Ozols, 1928, p. 136.

Diptera—
Lipara lucens, Meig. (CHLOROPIDAE). Brischke, 1880, p. 112.

Hymenoptera—
Cephus infuscator, Thoms. (CEPHIDAE). Forsius, 1912, p. 65.

Giraud (1863, pp. 1290–1292) reared specimens of "*Pimpla graminellae* Gravenhorst" from wheat stems in Austria. His description of the adult agrees very well with the present conception of *Pimpla detrita*, and he mentions the dentate labial ring of the larva. It is very probable that Giraud was dealing with our species. Failing to find the remains of any host, he considered that the parasite larva was phytophagous, at least in its later stages, but I think it more likely that the remains of the host were overlooked. *P. detrita* so scatters the fragments of *Cephus pygmaeus* among the particles of frass in the stem that they are often difficult to find.

No parasites of *Pimpla detrita* were obtained. On account of its early and rapid development and its ectophagous habit this species is certainly intrinsically superior to both *Collyria calcitrator* and *Pleurotropis benefica*. It does not come into conflict with *Hemiteles hemipterus*, which attacks the host at a much later stage. A first-stage larva of *P. detrita* and two first-stage larvae of *Microbracon terebella* were once found on the same host. Which of these two species is intrinsically superior could not be determined—I think the *Pimpla*.

In the first part of this paper the occurrence of *Pimpla detrita* in wheat stubble infested by *Cephus pygmaeus* is given as 2·12 per cent. This figure is based upon the examination of stubble only and is undoubtedly much lower than the percentage of parasitism of the species. Indeed it is very probable, judging from the data given above (p. 484), that *P. detrita* actually destroys about 5 per cent. of the *Cephus* population. It is a fact of interest in the theory of biological control that although *Pimpla detrita* is a simple parasite, a single individual destroying a single host, the number of hosts destroyed is about twice the number of parasites that live to reproduce.

Summing up these details to determine the value of *Pimpla detrita* as a controlling agent of *Cephus pygmaeus* and a possible enemy of *Cephus cinctus* in Canada, we have two outstanding facts :—(i) the percentage of parasitism of the species is about 5 per cent., but only about half of this population survives to reproduce ; (ii) the species is intrinsically superior to almost all, if not all, of the other parasites. In my opinion the benefit of the first fact is too slight to offset the harm of the second. For the present, certainly, *Pimpla detrita* should not be liberated in Canada.

9. Microbracon terebella, Wesmael.

The species of *Microbracon* are important primary parasites of a large number of insect pests. The catalogue of the Farnham House Laboratory contains nearly 300 "parasite and host" records with members of this genus in the former rôle. The recorded hosts include representatives of four orders :—Lepidoptera, Coleoptera, Diptera, and Hymenoptera. Lepidoptera are greatly in the majority, the references involving fourteen families, of which the PYRALIDAE, TINEIDAE, NOCTUIDAE, and TORTRICIDAE occur most frequently. Among the Coleoptera, the CURCULIONIDAE predominate, but there are several SCOLYTIDAE and CERAMBYCIDAE, and a few records of other families. TRYPETIDAE, CHLOROPIDAE, and a single Anthomyid represent the Diptera, and five TENTHREDINIDAE and the Eurytomid *Harmolita* are the only Hymenoptera.

At first glance there would seem to be no order in the selection of hosts by *Microbracon*. However, a closer study of the records, with particular attention to the ecology of the larvae utilized as hosts, leads to the discovery of a common factor. Many of the hosts are stem-borers (*Diatraea, Pyrausta, Aegeria, Cephus*) ; many live in fruits (*Cydia, Anthonomus*), in cotton bolls (*Platyedra, Earias*), or in buds, cones, or galls (*Evetria, Dioryctria, Pontania*) ; some are attacked while boring in wood or under bark (CERAMBYCIDAE, SCOLYTIDAE), or in hard seeds (*Bruchus, Apion*) ; several hosts live in webs or silken tubes in stored products (*Plodia, Ephestia*), others in rolled or spun leaves (*Tortrix*), and a few in cases (*Coleophora*). In short, in over 90 per cent. of the records the parasite is separated from the host by a covering of inert material. The parasite, therefore, is under the necessity of penetrating this covering with its ovipositor but, on the other hand, benefits in being protected by this same covering from the violent movements of the host immediately after it has been stung. For comparison and to test the significance of my data I have summarily reviewed the host records of another large genus of gregarious Braconids, *Apanteles*. The catalogue contains over 700 references to this genus. The same four orders act as hosts and the Lepidoptera are even more predominant but there is in addition a single reference to an Hemipterous (Coccid) host. I have made no actual counts, but I can assert confidently that the great majority of the host records refer to naked, external-feeding larvae. Taxonomically the hosts of both *Microbracon* and *Apanteles* are so diverse that one can see no order in their selection ; ethologically there is at least one common factor in each group. *Apanteles* selects naked, exposed hosts which it attacks directly, vis-à-vis ; *Microbracon* on the other hand, prefers hosts from which it is separated by an inert covering. The difference between the two genera in this respect is made more intelligible if one considers the fact recently pointed out by Imms (1931, p. 274) that ectophagous parasites rarely affect hosts living openly and exposed. The larvae of *Microbracon* feed externally on their covered host ; in their exposed host the larvae of *Apanteles* are endophagous. To this general rule, both as regards its selection of a covered host and as regards the ectophagous habit of its larva, *Microbracon terebella*, of course, conforms.

Female : Length, excluding ovipositor, 3·2 to 3·6 mm. Head, in front view (fig. 21, *b*), subcircular, a little wider than high ; seen from above, trapezoidal, narrower behind the eyes. Vertex and cheeks not margined by a carina ; smooth and shining, with only a few superficial piliferous punctures. Eyes oval, sparsely pubescent. Interocellar area prominently raised ; ocelli 1·5 times their own diameter apart, forming an equilateral triangle which is about the length of its own sides from the toruli, the eyes, and the occipital margin. Frons above the toruli deeply excavated, the concavity with a median ridge ventrally and a shallow median groove dorsally below the anterior ocellus, the surface finely coriaceous. Frons below the toruli swollen, its surface coriaceous but shining, at the sides of the clypeus smooth with superficial punctures. Clypeus depressed below the level of the frons, but its apical margin protuberant, semilunar, with a few small punctures. Oculo-malar

space as long as the mouth is wide, very finely rugulose and dull. Toruli above the middle of the eyes, about two-thirds their own diameter from the eyes and about the length of their own diameter apart. Antennae with 31 to 33 segments, slender, filiform; scape swollen, less than twice as long as broad; flagellar segments about 1·5 to 1·25 times as long as broad, none broader than long, all longitudinally ribbed and densely pubescent. Mandibles short and stout with two short teeth of which the dorsal one is the larger. Segments of maxillary palpi (fig. 21, *c*) 0·07, 0·07, 0·13, 0·14, 0·17 mm. long respectively; of labial palpi 0·08, 0·08, 0·10 mm. long respectively.

Thorax (fig. 21, *a*) about as high as wide and 1·5 times as long as wide. Pronotum rather long, shining, impunctate; its lateral lobes produced dorsally, with only a few fine punctures, depressed ventrally and there impunctate but with one or two irregular ridges. Mesoscutum strongly convex anteriorly, flattened posteriorly;

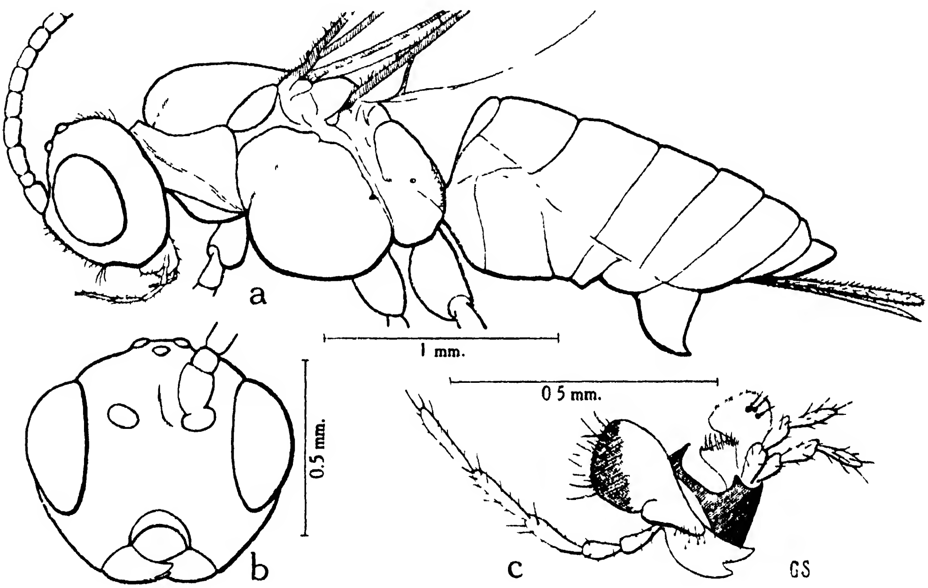

Fig. 21. *Microbracon terebella*, Wesm., ♀: *a*, lateral view; *b*, front view of head; *c*, maxilla and labium.

notauli very distinct, forming quite deep grooves anteriorly, shallower but wider posteriorly, where they actually reach the scuto-scutellar suture; parapsidal furrows absent; tegulae shaped like the valve of a mussel, smooth and shining, with a few obscure punctures laterally. Mesoscutellum prominent, rounded, about half as long as the mesoscutum; the scuto-scutellar suture with small pits. Mesepisternum raised under the tegulae then abruptly depressed at a pseudo-suture that appears to delimit a separate dorsal sclerite; the main plate of the mesepisternum rounded, convex, slightly depressed at the spiracle; prepectal suture absent. Mesepimeron reduced to a mere line. The whole mesothorax smooth and shining, practically impunctate except for a few fine piliferous punctures along the notauli, at the apex of the scutellum, and in an obscure line on the disc of the mesepisternum. Metanotum short, depressed. Metapleura narrow dorsally, broader ventrally above the coxae, with sparse piliferous punctures. Propodeon rounded, without areation, but with a triangular median ridge extending a short distance forward from the posterior margin; separated from the metapleura on each side by a deep furrow; the spiracles small, circular, above the middle of these lateral furrows.

Abdomen in dorsal view broadly elliptical, less than twice as long as wide. First tergite as in figs. 21, *a*, and 22, *a*, the median black part deeply and broadly grooved anteriorly, raised posteriorly. Second tergite (fig. 22, *b*) with a small circular swelling medially at the anterior margin, elsewhere without special structures, smooth and shining. Suture between the second and third tergites simple. Third and succeeding tergites smooth and shining, with a few fine piliferous punctures, very scattered on the disc, closer laterally. Ovipositor between one-third and one-half the length of the abdomen.

The ovipositor is exserted above the apparent sixth (morphological seventh) sternite. This, the so-called hypopygium, is produced medially on its apical margin and may be depressed (as in fig. 21, *a*) to permit the vertical insertion of the ovipositor. The morphological eighth tergite bearing the last pair of spiracles is produced downwards on each side in two lobes that almost meet in the mid-ventral line. The

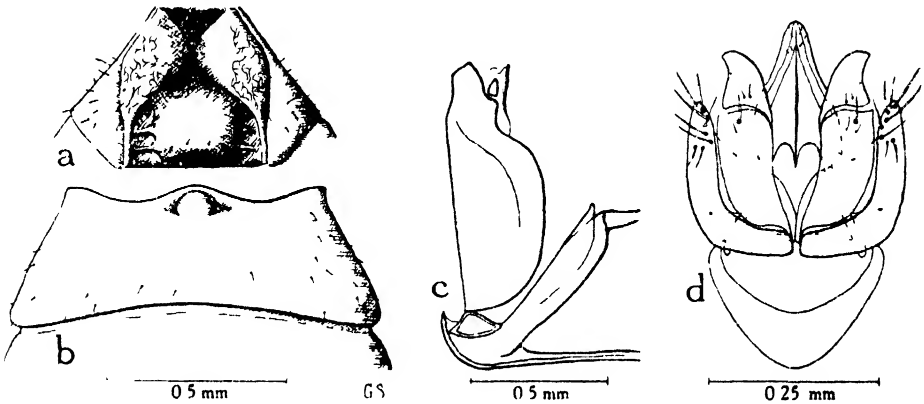

Fig 22 *Microbracon terebella*, Wesm *a*, first and *b*, second abdominal tergite of ♀ *c*, plates of ovipositor, *d*, genitalia of ♂

remaining sclerites and the plates of the ovipositor are essentially similar to those of the ICHNEUMONIDAE (see p. 51) and are represented in fig. 22, *c*.

Legs stout. Fore legs with the coxae somewhat flattened and produced posteriorly; femora stout; tibiae slender; tarsal segments 0·25, 0·15, 0·12, 0·10, 0·20 mm. long respectively. Middle legs similar. Hind legs with the coxae very stout, 0·40 mm. long; trochanters (together) 0·30 mm.; femora swollen medially, 0·75 mm.; tibiae 1·05 mm.; tarsi 0·37, 0·20, 0·15, 0·10, 0·20 mm. long respectively. Tarsal claws with a basal lobe pointed at its apex.

Fore wings considerably, hind wings a little, darkened basally, almost clear apically, with a hyaline streak across the first cubital cell. Stigma and veins dark brown; the stigma broad.

Head and thorax black; antennae black; mandibles usually black, sometimes dark ferruginous basally; palpi blackish, sometimes pale apically. Abdomen ventrally testaceous; dorsally usually black with only the extreme lateral margins of tergites 1 to 5 reddish; often more extensively reddish, the black being then confined to comparatively small areas in the middle of the tergites, the black area on the second tergite especially small and subcircular; occasionally entirely red. Legs also variable in colour; sometimes almost completely black; usually ferruginous at the apices of the femora and bases of the tibiae; sometimes with the femora and tibiae wholly ferruginous and with diffuse ferruginous marks on the coxae, trochanters, and tarsi. Palpi of ovipositor black.

Pubescence sparse, tawny yellow ; a few rather long, stiff hairs on the clypeus ; a sparse silky pile on the sides of the propodeon and ventrally on the meso- and metapleurae ; sides and apex of the abdomen with sparse, short, stiff hairs.

Male : Differs from the female only as follows :—Smaller, 2·6 to 3·2 mm. long ; more slender. Antennae longer, of 33 to 36 segments. Abdomen in dorsal view much more elongate, more than twice as long as broad. First tergite sculptured similarly to that of the female but less grossly so that the whole has a flatter appearance. Genitalia as in fig. 22, *d*. Legs more slender. Wings less darkened. Coloration of the abdomen even more variable ; at one extreme the whole dorsal surface of the abdomen and some of the sternites are black, at the other all the sternites and the third to fifth tergites are testaceous and the black on the second tergite is reduced to a small median subcircular mark.

The coloration of the abdomen, legs, and palpi in this species is so variable that its use in keys, especially when unsupported by other characters, renders determination difficult, uncertain, or impossible. In Marshall's key (1888) and in the more recent one of Fahringer (1927) only an occasional specimen of *terebella* would run to the correct place. Shchegolev (1930 ; see p. 483 above) has recently recorded *Microbracon abscissor*, Nees, from *Cephus pygmaeus* in Russia. I am not qualified to speak of the taxonomic validity of the two species, *terebella*, Wesmael, and *abscissor*, Nees, but certainly some of my English specimens, named *terebella*, having the apical segments of the palpi pale, would run to *abscissor* in Marshall's key. For the present the two names must represent two separate parasites of *Cephus pygmaeus*, one in England and the other in Russia, but there is a possibility that either by the synonymy of the two, or by the misidentification of one, only one species is actually concerned. It is high time that keys based on a variable coloration ceased to be copied or simply re-arranged and that more emphasis was placed on a search for truly diagnostic structural characters.

Oviposition of this species was not observed. Small larvae, probably in the second or third instar were first found on 29th July, feeding externally on their host. They occurred in the samples until 20th August, when the last feeding larvae were seen. On the same date cocoons of *Microbracon* first appeared and from that time only full-grown *Microbracon* larvae that had spun up were found.

The full-grown larva (fig. 23, *a*) is yellowish white with pale brown facial rods. It is firm in texture but rather translucent. In outline it is elongate elliptical, a little narrower anteriorly than posteriorly, and when extended measures 3·0 to 3·5 mm. in length, 1·0 to 1·3 mm. in width, and 1·0 to 1·2 mm. in thickness. Thirteen segments besides the head are clearly distinguishable ; the first and twelfth segments are collar-like and the head and anal segment respectively may be withdrawn into them. There are poorly developed dorsal humps on the median segments and prominent hypopleural swellings on segments 4 to 11. The dorsal lobe of the anal segment is larger than the ventral lobe and extends a little beyond it. The cuticle is shining and translucent and, except on the head, in the mid-ventral region, and on the dorsal humps, is closely studded with short triangular spicules (fig. 24, *e*) 0·012 mm. high and 0·008 mm. wide at the base. In addition each body segment bears four pairs of setae arranged in a single row around the middle (fig. 24, *f*) ; one pair just behind and outside the dorsal humps, one pair between this and the spiracles, one pair below the spiracles on the hypopleural swellings, and one pair on the ventral area.

The head is hemispherical ; its cuticle smooth and hard. The antennal organs are not conspicuous and consist of a short truncated cone only 0·017 mm. high and 0·01 mm. wide at the base upon a circular area about 0·05 mm. across. The labrum is poorly differentiated, but is represented by a transverse area about 0·12 mm. wide and 0·02 mm. high bearing two setae and two small papillae at each side. The base of the mandibles is broad and triangular ; the narrower, claw-shaped apex bears on its inner edge five prominent teeth, invisible when the mandibles are seen from the

front. The maxillary areas bear a tubercle set upon an 8-shaped sclerotic base, and three setae. The labial area bears the spinneret at its upper edge, a pair of tubercles raised on 8-shaped sclerotic bases, and four setae ranged in a curved row along its ventral margin. The facial setae are distributed as shown in figure 24, *a*.

The facial rods of this larva are essentially the same as those described above in the larva of ICHNEUMONIDAE but differ in one or two important points. The frontal struts are very short and the well-developed frontal arch crosses the face only a little above the mandibles. The mandibular and maxillary struts both join the labial struts and thus delimit a pair of genal areas each bearing a single seta. The labial ring is stout and simple. Internally the posterior tentorial arms pass directly across the posterior part of the head-capsule and meet to form a single stout transverse rod under the

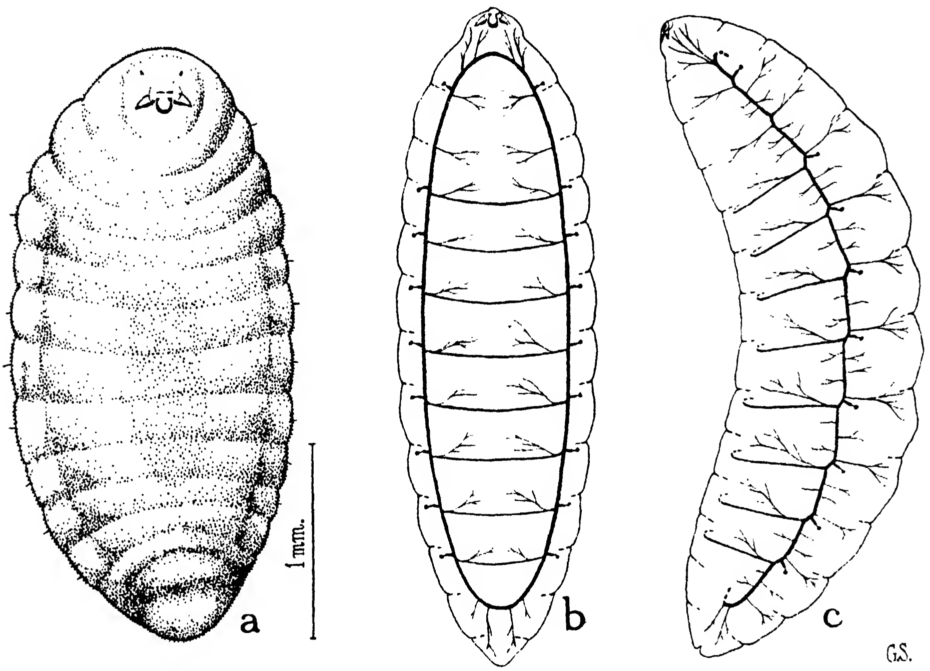

Fig. 23. *Microbracon terebella*, Wesm. : *a*, full-grown larva ; *b*, ventral and *c*, lateral view of tracheal system of full-grown larva.

pharynx. The anterior arms of the tentorium are very poorly developed, but are represented by a pair of fine colourless strands that extend forward a short distance from two points near the lateral extremities of the posterior arms. I have not found their anterior point of attachment. As usual, the floor of the pharynx is supported by a transverse sclerotization some distance behind the mouth-opening.

The lateral tracheal trunks (fig. 23, *b*, *c*) are connected anteriorly in the first and posteriorly in the twelfth segment. There are no accessory lateral commissures. The first pair of spiracles opens near the posterior margin of the first segment ; the remaining eight pairs of spiracles near the anterior margin of segments 4 to 11. There are ten pairs of ventral tracheae. Those in segments 2 and 3 leave the tracheal trunks in the anterior part of their segment, pass unbranched a considerable way towards the mid-ventral line, and then branch profusely. The eight pairs of ventral tracheae in segments 4 to 11 leave the tracheal trunks immediately behind the stigmatic trunks and soon form two principal branches. The anterior branch divides into many fine

tracheoles in the anterior part of its own and the posterior part of the preceding segment ; the posterior branch passes undiminished in size and almost unbranched to the mid-ventral line where it meets and joins its fellow from the other side. There are thus formed eight ventral commissures in segments 4 to 11. Dorsal tracheae leave the lateral trunks immediately in front of the spiracles in segments 4 to 11 and in the anterior parts of segments 2, 3 and 12. These remain undivided for a considerable length and then branch throughout the dorsal parts of the segment. Two pairs of tracheae leaving the lateral trunks in the first segment pass forward and ramify extensively in the head.

Usually the larvae of *M. terebella* do not kill their host until it has circumcised the stalk and put the plug of triturated wood into position, often not until it has spun its cocoon. Their own cocoons are then formed inside the hibernaculum of the sawfly. Occasionally the host is prematurely killed, and the parasite larvae then spin their cocoons in the lumen of the uncircumcised stalk. The cocoons are light brown in

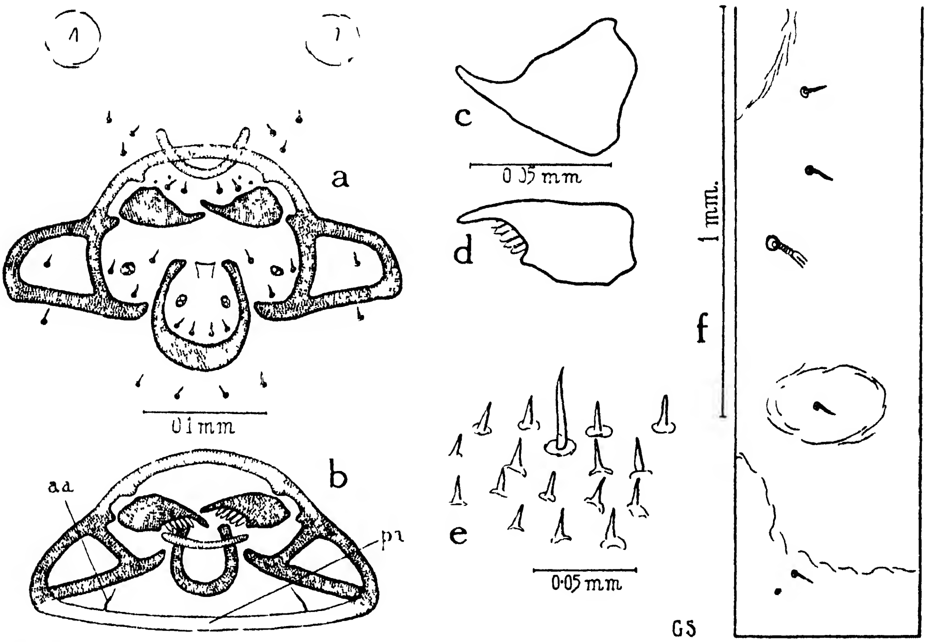

Fig. 24. *Microbracon terebella*, Wesm., full-grown larva : *a*, facial rods, mouth-parts, and facial setae from the front ; *b*, facial rods and tentorial arms from behind ; *c*, mandible, front view, and *d*, dorsal view ; *e*, cuticular spicules and seta ; *f*, left half of setal map of fifth segment.—*a.a.*, anterior, and *p.a.*, posterior arms of tentorium.

colour and closely woven so as to be quite tough. They are arranged lengthwise in the narrow cavity and therefore usually lie end to end, sometimes, when there are many together, with oblique overlapping ends (fig. 1, *b*). In this state, as full-grown larvae in their cocoons, these parasites pass the winter ; pupation taking place the following spring.

From one to seven individuals of *M. terebella* develop on a single sawfly larva 281 isolated groups of cocoons, representing, of course, the same number of *Cephu* larvae, included 924 individuals of *M. terebella*, an average of 3·3 individuals per grou or host. The groups tend to include individuals of one sex only ; of these 281 groups 176 (62·6 per cent.) contained females only, 73 (26·0 per cent.) males only, and

groups (11·4 per cent.) both males and females. The composition of the groups was as follows :—

No. of individuals in group	(1)	(2)	(3)	(4)	(5)	(6)	(7)
No. of male groups	3	5	25	16	15	6	3
No. of female groups	13	49	61	44	8	1	0
No. of mixed groups	0	2	10	12	6	2	0
Total no. of groups	16	56	96	72	29	9	3

It is worthy of notice that the average number of individuals in a male group (3·9) is greater than that in a female group (2·9). Of the 924 emergents 337 were males and 587 were females, a sex ratio of 36·5 males and 63·5 females per 100 emergents.

Emergence began in my outside cages on 5th May 1930, undoubtedly much earlier than it would in the field, and continued well into July. Specimens were seen in wheat fields at Harpenden on 28th June and were common by 2nd July, when several pairs were observed mating on flowering heads of *Heracleum*. Since no full-grown larvae or cocoons of *Microbracon* were found in these same fields until 20th August, I assume that *M. terebella* has only one generation a year on *C. pygmaeus* in England. Criddle (1923) and Seamans (1929) have established that *M. cephi* has two generations a year on *C. cinctus* in Canada.

The Curculionid, *Miarus campanulae*, Linnaeus, is recorded as a host of *M. terebella*. The first, and probably the only original, reference to this host is that of Brischke (1882, p. 136).

The head-capsules of first- and second-stage *Collyria* larvae are sometimes found entangled in the threads of *Microbracon* cocoons, showing that the host had been attacked by both species of parasites and that the *Microbracon* had been successful in destroying both the *Cephus* and the *Collyria* and in completing its development. *Microbracon terebella*, therefore, is intrinsically superior to *Collyria calcitrator*. How it compares with the other parasites I do not know. I think it is probably intrinsically superior to *Pleurotropis benefica* but inferior to *Pimpla detrita*. *Hemiteles hemipterus* attacks the sawfly so late in the season that it and *M. terebella* do not oppose each other for the possession of a host. They do, however, come into direct conflict, for occasionally, as described under that species, the *Hemiteles* acts as a hyperparasite on the *Microbracon*.

Besides the occasional parasitism of *Hemiteles hemipterus* (see page 504), which attains a frequence of about 4 per cent. of its groups or about 1·2 per cent. of its individuals, *Microbracon terebella* is occasionally attacked by three other species of parasites, namely: *Pezomachus terebrator*, Ratzeburg, *Eurytoma appendigaster*, Swederus, and *Habrocytus* sp.

Pezomachus terebrator, Ratzeburg, emerged only twice from about 500 isolated groups of cocoons. Both specimens were small, completely apterous females. Each had spun its own cocoon within and emerged from the topmost *Microbracon* cocoon of the group, while individuals of *M. terebella* emerged normally from the lower cocoons. It may be assumed, therefore, that *Pezomachus terebrator*, like *Hemiteles hemipterus*, attacks the group of *Microbracon* cocoons through the plug at the top of the hibernaculum and parasitizes the only one it is able to reach, the uppermost. Dr. Ferrière's determination of this species was confirmed by Dr. Roman.

Eurytoma appendigaster, Swederus, emerged seven times (3♂, 4♀) from about 500 groups of *Microbracon* cocoons, a parasitism of about 1·4 per cent. of the groups or

0·4 per cent. of the individuals. Only one *Eurytoma* came from a group, but unfortunately I neglected to observe whether only the topmost *Microbracon* was parasitized.

Habrocytus sp. emerged twice from about 500 groups of *Microbracon* cocoons. Both specimens were females. One emerged from the uppermost cocoon of its group ; the source of the other was not observed. I am sorry to be unable to give a specific determination of this species, but the genus is much in need of revision and neither Dr. Ferrière nor Dr. L. Masi, of the Museo Civico, Genoa, to whom the specimens were sent, felt justified in applying a specific name.

Microbracon terebella is the third parasite of *Cephus pygmaeus* in England in order of frequence, accounting for 2·77 per cent. of the sawfly population. Its value as a parasite in England is very slightly impaired by its liability to hyperparasitism ; more seriously by its tendency to premature destruction of the host, so that its numbers are reduced (perhaps as much as 20 per cent., see page 492) by cutting and harrowing operations ; and most especially by its intrinsic superiority over *Collyria calcitrator*, which would probably in any case destroy over 60 per cent. of its hosts. If its value in England is small, its worth in Canada would probably be even less, because another species of the same genus, *M. cephi*, Gahan, is already the most important parasite of *C. cinctus* in Western Canada ; the similar habits of the two species would inevitably bring them into competition and either reduce the value of the introduced species or diminish the control of the native form. The first fact, its low frequence, is sufficient to suggest that *Microbracon terebella* should not be used against *C. cinctus* until more important species have been tried ; the several subsidiary facts, especially the presence of a native species already attacking *C. cinctus* in Canada, seem to me to indicate that *M. terebella* is not suitable for introduction either at present or in the future.

10. **Pleurotropis benefica,** Gahan.

A puzzling variety of habits has been reported for members of the genus *Pleurotropis*. On the basis of his study of the African forms, Waterston (1915) suggested that " the species of *Pleurotropis* will prove to be hyperparasites upon other parasitic Hymenoptera." There are, however, several species that are undoubtedly primary parasites. Of forty-one records I have seen, thirty-one place *Pleurotropis* in a primary and ten place it in a secondary rôle. Ten of the former records have to do with Lepidopterous hosts, ten with Diptera (mostly AGROMYZIDAE), five with Coleoptera, and five with Hymenoptera (CEPHIDAE and *Synagris cornuta*). The remaining one doubtfully records *Pleurotropis africana* from the eggs of a Hemipteron. In the ten cases that species of *Pleurotropis* have been reported as secondary parasites, Chalcidoids have most frequently been the direct host ; Braconids in three cases. There seem, then, to be equally well substantiated records of species acting as primary and others acting as secondary parasites. This diversity may be only apparent and due either to insufficient study of the habits of the various species or to incorrect taxonomic definition of the group. It may, on the other hand, be real, in which case it will be essential to learn whether the diversity is inter- or intra-specific. Certainly with the available data it is impossible to generalize on the habits of this genus, and exponents of biological control must carefully judge the case of each species on its own merits.

There can be no doubt whatever that *Pleurotropis benefica* is a primary parasite of *Cephus pygmaeus*, for its development within the body cavity of that host has been observed and studied. It is impossible, of course, to prove that the species is never a secondary parasite, and I can only assert that in the course of my work, during which I have reared over 5,000 individuals, I observed no sign of hyperparasitic tendencies.

I have been particularly fortunate in having some of my reared specimens of *Pleurotropis benefica* determined by the author of the species. The identification was originally made by Dr. Ferrière. Subsequently, through the kindness of Dr. Harold Morrison, of the United States Bureau of Entomology, specimens were examined by Mr. Gahan himself, who reported that they certainly represent his species.

P. benefica was described in 1921 from specimens reared from *Trachelus tabidus* in Pennsylvania (Gahan, 1921) and has since been reported as a parasite of *Cephus pygmaeus* in New York (Ries, 1926). This is the first record of the species from Europe.

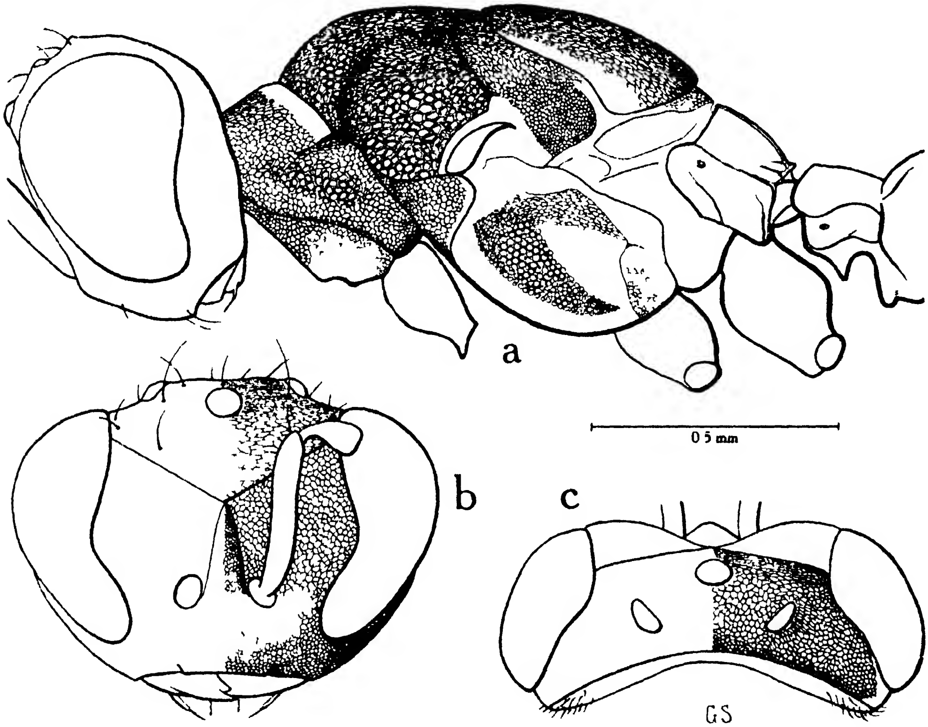

Fig 25. *Pleurotropis benefica*, Gah , ♀ *a*, head and thorax, lateral view , *b*, head, front view, and *c*, dorsal view

That the insect is really nearctic, however, is doubtful. *Trachelus tabidus* and *Cephus pygmaeus* are both European species recently introduced into North America, and it is likely that *P. benefica* is palaearctic and entered the United States with its Cephid hosts.

Female: Length, 3 to 3·5 mm. Head, in front view (fig. 25, *b*), subtriangular, 1·3 times as wide as long ; much wider than the thorax ; the occipital margin concave. Vertex flat but rather abruptly raised at the carinate occipital margin ; the surface entirely reticulate ; dark, dull green ; with ten to twelve stout, erect bristles. The concave occiput with a median smooth line, otherwise reticulately sculptured ; black ; dorso-laterally with a few dome-shaped swellings, each surmounted by a stout bristle. Cheeks narrow, not margined posteriorly by a carina ; coarsely reticulate ; dark green. Eyes large and oval; the inner orbits deeply, the outer and the dorsal orbits shallowly

emarginate; sparsely pubescent. Ocelli forming a flattened triangle; the inter-ocellar area raised but flat. Anterior ocellus round; posterior ocelli elliptical; the latter about their own long diameter from the eyes and the occipital margin. Frons depressed medially where four deep grooves meet. The upper pair of grooves forming a broad V; the frons between them flat, superficially reticulate, and shining; dark, dull green. The lower pair of grooves forming a narrow, inverted V; the frons between them increasingly strongly raised until it forms a prominent protuberance between the toruli; the whole irregularly reticulate or rugulose and dull. Frons at the sides of the grooves slightly convex but depressed ventrally about the toruli; reticulate, rather dull; purplish with coppery reflections, the median depression of the frons almost black. Frons below the toruli convex; the clypeus not clearly

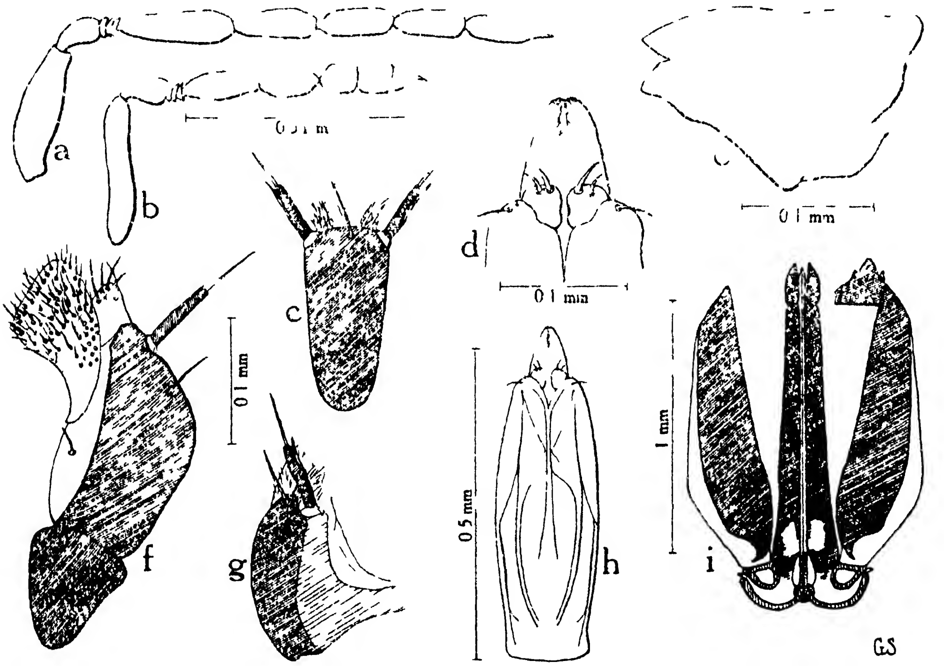

Fig. 26 *Pleurotropis benefica*, Gah *a*, antenna of ♂, and *b*, of ♀, *c*, labium of ♀, *d*, tip of genitalia of ♂, *e*, mandible, *f*, maxilla, and *g*, labium of ♀, *h*, genitalia of ♂; *i*, plates of ovipositor, ventral view

demarked; above only very superficially sculptured and shining, green and coppery; below finely but more deeply reticulate and dull, purplish black; the apical margin of clypeus and frons together shallowly concave. Oculo-malar space about as long as the distance between the toruli. Toruli much below the middle of the eyes, about 1·5 times their own diameter apart and the same distance from the eyes. Antennae of ten segments (fig. 26, *b*). Scape long, slender, slightly curved; anteriorly coarsely sculptured and dull, postero-laterally flattened and there smooth and shining; with a few short bristles; metallic green. Pedicel twice as long as wide; three ring segments very short. Sixth segment about three times as long as wide; seventh a little shorter and thicker, twice as long as wide; eighth and ninth almost square; tenth narrow, cap-like, terminating in a short spine; whole flagellum densely hairy, appearing black on account of its sculpture and pubescence but in a cross light dull metallic green. Mandibles (fig. 26, *e*) short and broad, with two stout apical teeth. Maxilla (fig. 26, *f*) with the cardo and stipes heavily sclerotized and dark; palpus one-

segmented, 0·06 mm. long, with a bristle arising about its middle lying closely appressed to its upper side, and another stout bristle nearly as long as the segment itself arising from its apex. Labium (fig. 26, *c*, *g*) with the mentum heavily sclerotized and dark; the palpi one-segmented, about 0·05 mm. long, with median and apical bristles like those of the maxillary palpi

Thorax (fig. 25, *a*) a little more than 1·5 times as long as wide, and as high as wide; except where otherwise stated shining metallic green with blue reflections. Pronotum long, posteriorly much narrower than the mesothorax; mostly reticulately sculptured but the narrow posterior margin, behind a low carina, smooth and shining; its lateral lobes reticulate. Proepisterna meeting in the mid-ventral line anteriorly, separated

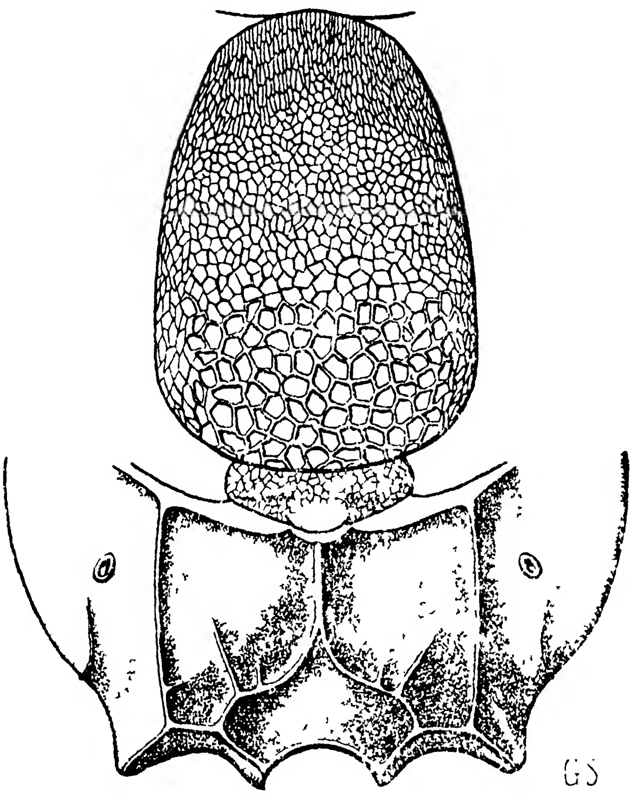

Fig 27. *Pleurotropis benefica*, Gah, ♀, mesoscutellum, metanotum, and propodeon

posteriorly by the triangular sternum, generally rather flat and reticulately sculptured but in front of the coxae swollen, smooth, and shining. Mesothorax abruptly constricted anteriorly to join the narrower prothorax. Mesoscutum generally convex but depressed on each side posteriorly, coarsely reticulate and shining; notauli distinct and suture-like anteriorly but losing themselves posteriorly in the lateral depressions of the mesoscutum; parapsides (following Tulloch, 1929) convex, reticulate, and shining dorsally; depressed, finely reticulate, and dull purplish ventrally. Mesoscutellum (fig. 27) prominent, oval, nearly 1·5 times as long as wide, as long as the mesoscutum; shining and reticulate, finely anteriorly, more coarsely posteriorly. Metanotum very slightly produced medially and there flat, smooth, and shining; to the sides slightly convex and reticulate; laterally depressed, purplish, and

only obscurely sculptured. Tegulae with fine curved striae, shining, metallic green. Prepectus forming a lobe in front of and below the tegula, reticulate. Mesepisternum in general convex, but with a large, subtriangular, dull green, depressed area closely covered with rounded pits; antico-ventrally and postero-dorsally superficially reticulate, elsewhere smooth or only obscurely sculptured and shining green with coppery tints. Mesepimeron shining; ventrally superficially reticulate; sometimes coppery. Metapleura raised to an angular prominence above the coxae, smooth and shining. Propodeon (fig. 27) broad and rather flat, smooth and shining, not at all reticulate; blue-green; the median carinae basally confluent for about half their length; lateral areas produced above the coxae; spiracles oval with raised margin, far outside the lateral carinae.

Abdomen ovate, flattened, about as long as the head and thorax together. Petiole wider than long, trapezoidal, broader anteriorly than posteriorly; its anterior margin carinate; with two pairs of lateral carinae; anterior lateral edge produced and fitting the posterior lateral edge of the propodeon; ventral anterior margin strongly produced downwards in the mid-ventral line; wholly reticulate and dull purplish. Second tergite concave anteriorly at the apex of the petiole; its surface smooth and shining green anteriorly, duller, slightly purplish, and superficially reticulate posteriorly. Third to seventh tergites finely reticulate, dull, and purplish black, except on the apical margins which tend to be more shining and greenish. Eighth tergite shining, greenish, reticulate. Venter shining, dull coppery-green, weakly reticulate. Ovipositor not exposed; its plates as in figure 26, *i*; the quadrate plates broad, heavily sclerotized, and forming posteriorly the mid-ventral wall of the abdomen.

Front femora broad, flattened beneath, 0·48 mm. long; tibiae 0·45 mm. long; tarsi 0·07, 0·10, 0·07, 0·12 mm. long respectively. Middle legs with these segments 0·45, 0·60, 0·10, 0·12, 0·10, 0·15 mm. long respectively. Hind legs with coxae large, the femora and succeeding segments 0·60, 0·70, 0·10, 0·15, 0·10, 0·15 mm. long respectively. All coxae, femora, and tibiae with gross sculpture. Legs except the tarsi metallic green; tarsi brownish black.

Wings hyaline. Front wings with the marginal vein more than twice as long as the submarginal; post-marginal a little longer than the stigmal.

Male: Differs from the female only as follows: A little more slender. Antennae (fig. 26, *a*) much longer; scape stouter; sixth segment three times as long as wide; following three segments sub-equal in length, about twice as long as wide; apical segment narrower than the preceding and a little longer, nearly three times as long as wide, terminating in a short spine; all the segments coarsely sculptured and metallic green with coppery tints; the flagellar segments hairy. Petiole of abdomen longer than wide; slightly broader anteriorly than posteriorly; anterior lateral edge not so much produced; the mid-ventral line strongly keeled and produced downwards both anteriorly and posteriorly. Second tergite almost wholly green, smooth, and shining. When fully exposed the third to eighth tergites much as in the female but narrower, less noticeably reticulate, and shining green with coppery tints; usually telescoped so that the third to sixth tergites seem very short and broad and the seventh tergite abruptly narrowed, the abdomen then appearing truncated posteriorly. Genitalia as in figure 26, *d* and *h*; long and slender. Legs more slender.

I have not observed the oviposition or seen the egg of this species. The youngest individuals examined were dissected from the body cavity of larvae of *Cephus pygmaeus* on 15th July 1930. These young larvae were very stout, being 0·9 to 1·0 mm. long, and 0·4 to 0·45 mm. wide. The head was comparatively very small (about 0·09 mm. long and 0·1 mm. wide) and so much narrower than the first segment that it had the appearance of a tubercle set on the end of the body. The mandibles were similar to those of the full-grown larvae described below, but more slender and only 0·035 mm. long. By the middle of August 1930, only mature larvae

of the parasite were to be found. At that date most of them were still enveloped in the skin of their host, but this covering was soon discarded and pushed to the bottom of the hibernaculum. In this state, without spinning any cocoon, the larvae pass the winter.

The full-grown larva is white, firm, small, and rather stout. It is cylindrical in shape and only slightly narrowed anteriorly and posteriorly. When fully extended it measures 3·5 to 4·0 mm. in length and 1·0 to 1·2 mm. in width. A head and thirteen body segments can be clearly distinguished, but the anal segment is very small and is usually retracted into the twelfth, as the head is retracted into the first. The cuticle is smooth, shining, and transparent, without conspicuous papillae or setae.

The head in this stage (fig. 28, *a*) is not markedly narrower than the first body-segment. The antennal organs are poorly developed, being only circular swellings raised less than half their basal diameter. The small mandibles are the only conspicuous cephalic appendages. These (fig. 28, *b*) are about 0·09 mm. long and consist of a broad base carrying a simple curved tooth about 0·04 mm. long. The mandibles are supported by tentorial structures which, however, are not darkened and are comparatively inconspicuous. The most noticeable is a short, stout rod connecting

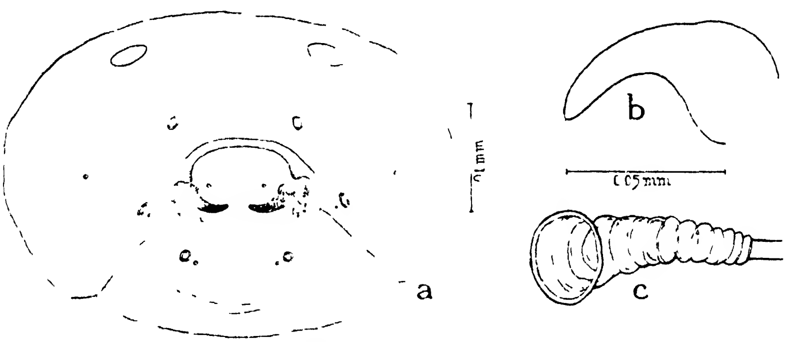

Fig. 28. *Pleurotropis benefica*, Gah., full-grown larva: *a*, head, front view; *b*, mandible; *c*, spiracle.

the bases of the mandibles. A slender, colourless arch above the oral cavity and another below it are to be considered as slight thickenings of the integument, but the extremities of the dorsal arch are thickened and darkened and turn inwards to form the dorsal articulations of the mandibles. No circular apodeme, such as that described by Parker (1924) in many Chalcidid larvae, could be found. Seven pairs of sensoria, three large and four small, are found in the oral region and are distributed as shown in figure 28, *a*.

The lateral tracheal trunks are united anteriorly in the first and posteriorly in the eleventh segment (fig. 29, *a*, *b*). They communicate with the outside through seven pairs of functional spiracles (fig. 28, *c*) situated laterally near the anterior margin of segment 2 and segments 5 to 10. A sclerotized ring, resembling a spiracular opening, occurs in a similar position on segment 4 but is not connected with the tracheal system. Short tracheae resembling stigmatic trunks leave the lateral trunks in segments 4 and 11 but end abruptly before reaching the surface. The functional stigmatic trunks are rather long and increase gradually in diameter as they approach the spiracle. Dorsal and ventral tracheae leave the lateral trunks in segments 2 to 10 near the origin of the stigmatic trunk; sometimes the dorsal tracheae arise from the base of the latter. Neither the dorsal nor the ventral tracheae maintain their size, but divide profusely to form a number of very fine branches. Anteriorly a pair of tracheae leave the trunks in the first segment and enter the head; posteriorly fine tracheae leave the trunks in the eleventh segment and supply the twelfth and thirteenth segments.

The larva passes the winter lying naked in the cocoon of its host. In the spring it discharges the contents of its gut and enters a pre-pupal stage that lasts, at 25° C., about two days. Then, even before it has cast off the last larval skin, it begins to darken. Within a few hours after the larval skin has been shed the pupal envelope is completely black (fig. 29, *c*) and quite hard. Hymenopterous pupae are usually of the exarate type but this might be more fittingly considered obtect since the pupal envelope is hard and the appendages are fastened to the body. Moreover, when the adult *Pleurotropis* emerges the pupal envelope is not shed as a soft crumpled tissue, as is usual among the Hymenoptera, but retains its shape and volume in a manner similar to the empty pupal case of a Lepidopteron.

Pleurotropis benefica is the last of the parasites of *Cephus pygmaeus* to emerge. In 1930 it appeared in my cages about twelve days after its host. The sex of most of

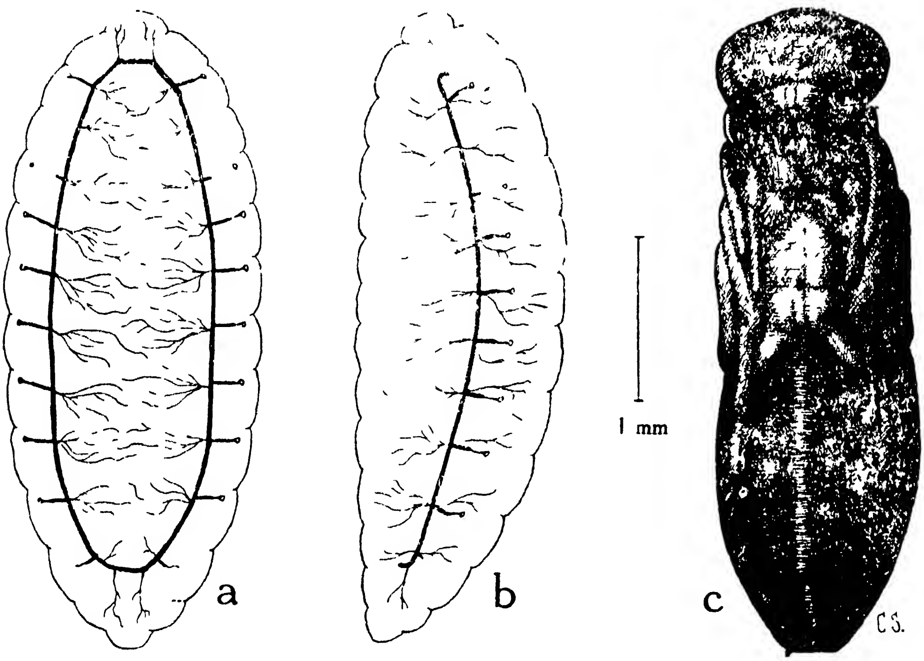

Fig 29 *Pleurotropis benefica*, Gah *a*, ventral, and *b*, lateral view of tracheal system of full-grown larva, *c*, pupa.

my emergents was not recorded. The emergents from a small random sample of larvae included 54 males and 176 females, a sex ratio of 23·5 males and 76·5 females per 100 emergents.

Only a single individual o *Pleurotropis benefica* develops in each host. It is of interest, therefore, in passing, to note the small size of this parasite in comparison with the others that utilize the same host. No significant difference was observed in the size of the individual hosts attacked by the several species of parasites and yet, on what seems to be the same quantity of food, there develop such comparatively large parasites as *Hemiteles hemipterus*, *Pimpla detrita*, and *Collyria calcitrator*, each two or three times as large as *Pleurotropis benefica*, or else three or four individuals of the gregarious *Microbracon terebella*, each as large as the solitary Chalcid. I do not think that this can be attributed to an accelerated development of the hosts of *Pleurotropis*, both because my observations show no sign of such an effect and because

one of the large parasites, *Pimpla detrita*, emerges from hosts prematurely killed. Nor can it be due to an extended feeding period of the hosts of the other species for the same reasons and, in addition, because *Hemiteles hemipterus* attacks the host after it has finished feeding. I suppose the result is due to the more wasteful metabolism of the smaller parasite.

The only two known hosts of *Pleurotropis benefica* are *Cephus pygmaeus* (Ries, 1926, p. 293) and *Trachelus tabidus* (Gahan, 1921, p. 119).

No hyperparasites of *P. benefica* are known. The larva has so few sclerotic parts that to find its remains after its host has been attacked by another species of parasite is practically impossible. I have not, therefore, been able to determine and can only assume that the ectophagous major parasites of *Cephus pygmaeus* are all intrinsically superior to the endophagous Chalcid. Since the other endophagous species, *Collyria calcitrator*, parasitizes 71·13 per cent. of the host population it is probably present in that proportion in the hosts attacked by *Pleurotropis*. Yet, in a careful examination of the remains of the hosts of several *Pleurotropis*, I have been unable to find any trace of *Collyria*. Unless the two species attack ecologically discrete groups of hosts, which is very unlikely, this must be taken to indicate that *Pleurotropis* can develop only when *Collyria* is not present. It is highly probable, therefore, that the Chalcid is intrinsically inferior to *Collyria* as well as to the other major parasites of the sawfly.

The intrinsic inferiority of *Pleurotropis* to *Collyria* gives it a sort of " buffer action." When the two operate together, the Chalcid has comparatively little effect since 71·13 per cent. of its population is annually destroyed by the superior parasite and the frequence of those that survive is only 3·95 per cent. If the numbers of *Collyria* decreased, more *Pleurotropis* would escape, and if the former suddenly disappeared, in the first year of its absence *Pleurotropis* would have a frequence of 13·68 per cent. This figure, in the continued absence of the superior parasite, might be expected to increase still more.

Pleurotropis benefica is the second most important parasite of *Cephus pygmaeus* in England in point of numbers, accounting for 3·95 per cent. of the sawfly population. The species already exists in North America as a parasite of *Cephus pygmaeus* and *Trachelus tabidus*, and when its range reaches that of *Cephus cinctus* it may be expected to attack the latter. Moreover, an allied species, *Pleurotropis utahensis*, already occurs in Canada and attacks that part of the *Cephus cinctus* population feeding in grasses. For the present I have recommended to the Canadian entomologists that the individuals of *Pleurotropis benefica* obtained as by-products in the collection of *Collyria* be destroyed. However, if in the future an auxilliary parasite to assist *Collyria calcitrator* is wanted, *Pleurotropis benefica* is the one of my English parasites that should be investigated first.

IV. Natural Control of *Cephus pygmaeus*.

To produce a satisfactory account of the natural control of *Cephus pygmaeus* in England would require several years of uninterrupted research. The time I have been able to devote to the problem has been limited to two winter seasons and infrequent field excursions during part of one summer. Obviously, then, any discussion of the subject that I can write will be very incomplete. However, I have thought it best to conclude the present paper with a summary of the available data, and in the following brief discussion I shall sketch the broad outlines of the problem so far as they are apparent after so little work.

In Bottom Common Field there were, on an average, very nearly two hundred stalks of wheat per square yard (Table I, page 489). In July (Table I), 18·3 per cent. of these stalks were infested by *Cephus pygmaeus*. Owing to causes almost entirely unknown and referred to above simply as a mortality among the larvae, this infestation gradually declined until on 20th August, when the grain was cut, it was only 10·1 per

cent. (Table I). This initial reduction in the numbers of the pest, observed but not studied, is very important and cries aloud for investigation. It may be largely due to the action of what Thompson & Parker (1928) call " intrinsic factors."

A farm operation, cutting, next reduced the sawfly population 23 per cent., so that immediately after it the stubble was only 7·8 per cent. infested (p. 000). This reduction depends on the time of cutting and is greater the earlier the wheat is cut.

Not all of these infested stalks contained living *Cephus*, however ; a great many were occupied by parasites or by dead or doomed sawfly larvae. In 2·98 per cent. of the infested stalks the *Cephus* larva was found dead and impregnated with the mycelia of fungi. These fungi were not determined. They may have been entomogenous and have caused the death of the larvae, or they may have been saprophytic and have simply grown on the larvae killed by other unknown factors. The figures for the parasites have already been given : *Hemiteles hemipterus* and the minor parasites together represented 0·68 per cent. of the *Cephus* present in the stubble ; *Pimpla detrita* 2·12 per cent. ; *Microbracon terebella* 2·77 per cent. ; and *Pleurotropis benefica* 3·95 per cent. Of the living sawfly larvae found in the stems 71·13 per cent. contained within them the developing larva of *Collyria calcitrator* and were doomed never to attain the adult stage. The infestation by living unparasitized *Cephus* larvae during September and October therefore was only 1·97 per cent. of the wheat stalks*.

During the winter months several factors still further reduce the *Cephus* population. A certain number, surely, would succumb ordinarily to the rigours of the winter season, and when, as is usually the case in England, the stubble is ploughed and harrowed during October the mortality due to mechanical injury, to exposure if the hibernaculum be broken open, to extremes of temperature and humidity if it lie on the surface, to inability to emerge if it be buried too deeply, must be very considerable. Unfortunately we have no reliable figures at all on these matters.

Of the *Cephus* larvae that survive the winter and emerge in the adult stage approximately only half are females. Several factors operate on these females to reduce still further their effective reproduction ; a small proportion may fail to mate, others may be destroyed by predators or meet with accident before reproduction. Finally, since only one larva develops in a wheat stem, a part of the progeny is lost whenever more than one egg is laid in a single stalk.

Unsatisfactory as this general survey is, it is sufficient to indicate that even in Bottom Common Field, the most heavily infested field that could be found, considerably fewer than 1 per cent. of the wheat stems produced female sawflies that effectively reproduced their species.

Fortunately, the part of this account that particularly concerns us here, the part played by the parasites, is fairly well documented and some actual figures and conclusions can be derived from the data available. Let us compare (Table II) the conditions obtaining in an acre of Bottom Common Field at present, as outlined above, with those that would occur the year that : (i) *Collyria calcitrator* ; (ii) *Pleurotropis benefica*, disappeared.

The unknown factors operating later, during the winter, would presumably destroy an approximately equal proportion whatever the population so that the figures remain relatively the same in the spring.

It will be immediately observed that in the absence of *Collyria calcitrator* the sawfly population at the end of one year would be more than three times as large as it is at present. It is impossible to estimate with any degree of accuracy what would happen in the second and succeeding years without using the reproductive rates of

* This is on the basis of the stubble infestation (7·8 per cent.) of the experimental plot. If the stubble infestation (9·8 per cent.) of the field as a whole is taken, we have 2·47 per cent. of the stalks containing living unparasitized *Cephus*.

the several species concerned and these, unfortunately, are unknown. Since, however, as far as can be judged from two years' observations, the sawfly population under present conditions remains approximately constant, it must be assumed that the disappearance of *Collyria calcitrator*, allowing three times as many sawflies to reach maturity in the first year, would permit a higher general level of population and might easily lead to a serious outbreak.

TABLE II.

Summary of Cephus *Infestation in Bottom Common Field.*

	Number of *Cephus* at present	without *Pleurotropis*	without *Collyria*
968,000 stalks in 1 acre.			
18·3 per cent. of stalks infested in July	177,744	Same	Same
10·1 per cent. of stalks infested before cutting	97,768	,,	,,
7·8 per cent. of stalks infested after cutting	75,504	,,	,,
2·98 per cent. of larvae mouldy, leaving	73,254	,,	,,
0·68 per cent. killed by *Hemiteles*, leaving	72,741	,,	,,
2·12 per cent. killed by *Pimpla*, leaving	71,140	,,	,,
2·77 per cent. killed by *Microbracon*, leaving	69,049	,,	,,
3·95 per cent. killed by *Pleurotropis*, leaving	66,067	69,049	58,721*
71·13 per cent. of remainder killed by *Collyria*, leaving ...	19,074	22,056†	58,721

* "Buffer action," 13·68 per cent. killed by *Pleurotropis*.

† 71·13 per cent. of 66,067, since the 3·95 per cent. usually killed by *Pleurotropis* are all free of *Collyria*.

The absence of even the best of the other parasites, however, if *Collyria* remain, produces comparatively little effect on the numbers of *Cephus*.

The non-living factors take a tremendous toll of the sawfly population, but they remain more or less constant from year to year and are in any case only very slightly amenable to human modification. I am of the opinion that *Collyria calcitrator* is the most important single factor in the control of *Cephus pygmaeus* in England.

The very high frequence of *Collyria calcitrator* in England, its perfect adaptation to and complete concentration on the wheat-feeding CEPHIDAE ; its independence of alternate hosts ; its ability, as indicated by its wide range, to exist under very different climatic conditions ; all give reason to expect that its introduction will have a very beneficial effect on the sawfly infestation in Canada.

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COLONISATION IN CANADA OF *COLLYRIA CALCITRATOR* (HYM. ICHN.), A PARASITE OF THE WHEAT-STEM SAWFLY.

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In response to the expressed desire of Mr. Arthur Gibson, Dominion Entomologist, to introduce European parasites to aid in controlling the Western Wheat-stem Sawfly, *Cephus cinctus*, a shipment of 15,000 wheat stubs containing parasitised *Cephus pygmaeus* was forwarded to Canada from the Farnham House Laboratory, Farnham Royal, Bucks, England, in the early spring of 1930. This stubble was received at the Dominion Parasite Laboratory, Belleville, Ontario, and was there held in cold storage until reshipped to Western Canada, where the parasite, *Collyria calcitrator*, was to be liberated.

The material was collected in England under the direction of Dr. George Salt, of the Farnham House Laboratory, during the winter of 1929–1930 and shipped to Canada on 20th March. The stubble containing the hibernating larvae in their cocoons was packed in 15 tins, each containing 1,000 larvae, the tins being packed in four wooden boxes tightly sealed and sewn up in heavy cotton wrapping. The shipment was forwarded by express, being kept in cold storage (40° F.) from Southampton to Montreal, and delivered at the Belleville Laboratory on 2nd April.

On receipt at the Laboratory, one of the boxes was opened and examined. The contained larvae were, to all appearances, in excellent condition, and after repacking this box was placed with the remainder of the shipment in commercial cold storage (32°–40° F.) to retard development until emergence was desired.

After some deliberation, Swift Current, Saskatchewan, was selected as the most favourable point to attempt colonisation of the parasite, and the writer arrived there on 7th June to make preparations for the season's work. Swift Current is a small city located in the centre of the area most heavily infested with sawfly in Saskatchewan, and no parasites had so far been taken from hibernating sawfly larvae in this area. An Experimental Station of the Dominion Experimental Farms Branch is located at this point, and, through the courtesy of the Director, suitable working facilities were provided on the Station farm.

A portable granary, placed at our disposal by the Station, was fitted up as an insectary and a " safety " cage constructed inside to prevent the escape of any insects from the material.

Acting on the advice of Dr. W. R. Thompson, Superintendent of Farnham House Laboratory, the greater part of the material was forwarded to Swift Current for emergence. The stubble was left in the tightly sealed tins as received from England, and these were packed in a well insulated ice-box which was kept iced *en route* by the Express Company. The shipment left Belleville on 10th June and reached Swift Current on 13th June. The material was in excellent condition and was spread out on trays in the " safety " cage for emergence.

Emergence of *Collyria* commenced almost immediately and continued until 7th July. Five days later the remaining stubble was destroyed by burning. A total of 6,323 adult *Collyria* were reared from this material. Of these 3,719 were females and 2,604 were males. The peak of emergence was reached on 23rd June with an emergence on that date of 1,386 individuals.

A number of adults of other species also emerged from this material. These were killed as soon as observed and were later determined as follows : 18 *Hemiteles hemip-*

* Contribution from the Dominion Parasite Laboratory, Belleville, Ontario.

terus, Fabricius, 5 *Leptocryptes bellulus*, Kriechbaumer, 27 *Microbracon terebella*, Wesmael, 2 *Microbracon exhilarator*, Nees, 193 *Pleurotropis benefica*, Gahan, 7 *Polygnotus pleuron*, Walker. *Cephus pygmaeus* adults did not begin to appear in numbers until after the emergence of *Collyria* had reached its peak, a fact which greatly facilitated the handling of the parasite.

One thousand wheat stubs were retained at Belleville in order to determine the ability of *Collyria calcitrator* to withstand shipment as adults. A total of 427 adults was recovered from this stubble. The first shipment of 210 adults left Belleville on 14th June and reached Swift Current three days later with a mortality of 8 per cent. These parasites were released in the field on the date of their arrival and appeared normally active and vigorous. A second shipment of 214 adults received at Swift Current on 20th June did not fare so well and suffered a mortality of 65 per cent. In the second shipment the inner cage was badly damaged *en route* and the high mortality was, without doubt, partly due to rough handling in transit. Lack of additional material prevented further trial of such shipments, and the ability of *Collyria* to withstand shipment as adults remains in doubt.

A superficial examination was made of wheat fields in the vicinity of the Experimental Station previous to the emergence of *Collyria*, and three fields promising a heavy and early infestation of sawfly were selected for liberations of *Collyria*. These fields were within three-quarters of a mile of one another and, with the exception of one field, were on the Experimental Station lands. Field A was a field of Reward Wheat sown on fallow ; field B, Marquis Wheat sown on a fresh breaking of prairie sod, and field C, Marquis Wheat sown on the previous year's stubble.

Sawfly infestation in these fields during and following the liberation period was as follows :

	No. stems examined	Per cent. stems infested	Per cent. stems infested with eggs only	Per cent. stems infested with eggs and larvae	Per cent. stems infested with larvae only
Field A.					
19 June	110	76	73	2	1
28 ,, ...	25	84	12	24	48
4 July	350	80	4	31	45
Field B.					
25 June	150	60	50	9	7
8 July	400	46	1	1	44
Field C.					
30 June	180	49	8	3	38
14 July	400	38	*	*	*

* Stage of sawfly not recorded, but mostly larvae.

A glance at the last three columns above, indicates clearly the increased development of the sawfly as the season advanced.

Liberation of parasites was begun on 17th June with the release of 193 adults received on that date from Belleville. The final liberation was made on 30th June. The first four liberations, totalling 2,318 parasites, were made in Field A during the period 17th to 23rd June, inclusive. The following two liberations of 2,250 parasites were made in Field B on 25th and 26th June. The last two liberations of 1,202

individuals were made in field C on 27th and 30th June. The number of female *Collyria* released in each field was as follows :

Field A	1,107 females
Field B	1,421 females
Field C	1,064 females

It was with some concern that the first parasites were released in their new environment in the presence of what it was hoped they would accept as their new host. A dozen or so of the insects were followed in flight but all turned out to be males, and it was impossible to find a single female at this time. Two days later, however, it was only a matter of a few minutes before several females were found working over wheat-stems with much excitement, and three were found with ovipositors inserted in stems. One such stem was opened and a sawfly egg found at the point of attack. On dissection a few hours later this egg was found to contain a parasite egg. At all subsequent liberations, females were observed to settle down to hunting without delay and parasite eggs were again found in attacked sawfly eggs. In all cases observed host eggs and not larvae had been selected by the parasite, although in one case the parasitised host egg was sufficiently well advanced to show the disposition of the embryo within. How the parasite locates the host egg it is difficult to say, but it appears possible and likely that the ovipositor is thrust through the scar left by the ovipositor of the host. In this way the parasite would be sure to find the host egg fastened to the inner wall of the stem.

The extent of dispersal and longevity of females in the field were not determined. One female, however, was found at the point of liberation at least four days after release, and a second was found 200 yards from the point of liberation at least seven days after release. This second female was found flying about under conditions of cloudiness and air movement sufficient to hold sawflies at rest on the wheat-stems.

Owing to the impossibility of separating infested from non-infested plants while still green, no attempt was made to determine the progress of the parasites at the liberation points until after harvest, when mature sawfly larvae were to be found enclosed in their cocoons in the stubble. Following harvest, collections of stubble infested with sawfly were made at the liberation point in each of the three fields, and in fields A and B additional collections were made at twelve and twenty paces from the liberation point.

The sawfly infestation at the time of these autumn collections appeared much reduced, the percentage of infested stubs in the three fields being as follows :

Field A	2–6 per cent.
Field B	6–9 per cent.
Field C	5 per cent.

All larvae taken in the collections were examined for parasitism. At first each larva was dissected, but later it was found possible, with a little manipulation, to detect the brownish head-capsule of contained parasites through the integument of the host, and dissection was abandoned.

Four parasitised *Cephus cinctus* larvae containing parasites and two parasite larvae were forwarded to Dr. Salt for examination, and in a subsequent letter he quotes from his records : " The two larvae are certainly stage II *Collyria calcitrator* and the four *C. cinctus* all contain stage II larvae of the same species. It is now certain, then, that *C. calcitrator* has successfully attacked *C. cinctus* and has developed in the new host to the second larval stage."

The recovery of even small numbers of parasites is extremely encouraging, for with such a large host population a high percentage of parasitism could not be expected.

The results of the collections were as follows:

	No. *C. cinctus* collected	No. containing parasites	Parasites	
			alive	dead
Field A				
Liberation point	288	8	3	5
12 paces from liberation point ...	309	9	8	1
20 paces from liberation point ...	105	2	1	1
Field B.				
Liberation point	363	1	0	1
12 paces from liberation point ...	30	0	0	0
20 paces from liberation point ...	100	0	0	0
Field C.				
Liberation point	20	0	0	0

The difference in successful establishment of the parasite in the three fields appears to be linked up with the date of liberation and the biology of the host. It is well known that even though a wheat-stem may contain a dozen or more sawfly eggs in mid-season, only one larva survives to maturity, and the successful larva appears to be the oldest inhabitant of the stem, which destroys all the younger larvae and eggs, whether parasitised or not. An examination of the infestation records made at the time the liberations were commenced in each field reveals not only a greater percentage infestation in Field A, but also that a smaller percentage of the egg-containing stems harboured larvae. This is significant in view of the fact that stems containing host eggs attract oviposition, while parasite eggs placed in such stems are inevitably destroyed by the older host larva. Thus in Field C, 28 per cent. of the stems containing eggs ("eggs only" + "eggs and larvae") also contained larvae. In Field B, 15 per cent. of the egg-containing stems also contained larvae, while in Field A, only 3 per cent. of the egg-containing stems contained larvae. The chances of survival for the parasite were, therefore, much greater in Field A than in either B or C, and this more favourable condition was due to the less advanced stage of infestation by the sawfly at the time when the *Collyria* were liberated. The season's investigations indicate that liberations in Field B and C were too late to give *Collyria* the optimum conditions for establishment, and with additional material in view for 1931 it is planned to improve the conditions for establishment by making earlier liberations.

THE EFFECT OF CLIMATE ON THE MIGRATIONS AND BREEDING OF *LOCUSTA MIGRATORIOIDES* IN NIGERIA.

By OWEN B. LEAN, B.Sc., D.I.C., F.E.S.

An outline of the general course of the swarming of *Locusta migratorioides*, R. & F., in tropical Africa from 1928 to April 1931 was given in a previous paper.[4] There it was shown that the flights had kept within certain limits corresponding with three belts of vegetation as classified by Shantz[7], viz.: (*a*) high grass—low tree savanna; (*b*) Acacia—tall grass savanna; (*c*) Acacia—desert grass savanna. To these a fourth, the " mountain grass " should be added.

The establishment of these vegetation belts depends on various factors, of which climatic humidity is probably the most important, and it appears that the range of the locust does not depend so much on the vegetation as upon the climate that is partly responsible for the vegetation. These belts are therefore indicators of the climatic zone that is suitable for the migratory flights. Within the wide area covered by the foregoing types of vegetation the movements and behaviour of the swarms are influenced by various climatic elements, and the present paper is an attempt to correlate the main movements and breeding seasons with the seasonal climatic changes from the first important influx of locusts into Nigeria in December 1929 to April 1931.

Nigeria appeared to be an especially promising field for this study since there were available some 2,300 records of swarms within a wide and nearly complete cross section of what appears to be the dispersal belt.

This analysis has proved so suggestive that it seemed worth while to collate at once the available data, although the infestation still continues. Further evidence to be obtained during the continuation of the swarming, as well as the study of past migrations in other territories, may either confirm or qualify the hypotheses suggested by what can only be regarded as a preliminary survey. It is hoped, however, that this paper will not only assist in the forecasting of migrations and breeding seasons of the Migratory Locust but will encourage detailed study along similar lines before the opportunity is lost.

Outline of the Nigerian Infestation.

It will be convenient to adopt here the same enumerations of the periods and generations that were proposed in the previous paper.

Period V. October 1929–March 1930.

A very few swarms were reported in north-western Nigeria in September and November. These were probably the F.4 adults derived from breeding in the Upper Volta or western Niger.

The main influx of swarms of this generation into south-western Nigeria began in December. By the end of the month the swarms had covered Abeokuta and northern Oyo Provinces and had reached southern Ilorin and Kabba Provinces, and one swarm passed Benin. In January they reached Niger, Benue, Onitsha and Ogoja Provinces. By March they had reached Plateau Province and at this time all the Provinces mentioned (except Benin, Onitsha and Ogoja) were infested.

Period VI. April–July 1930.

The movement of the F.4 flights continued to the north, north-east and east. In April all the Northern Provinces had been invaded, though only a few swarms had reached the extreme north. The last of this generation died in early June.

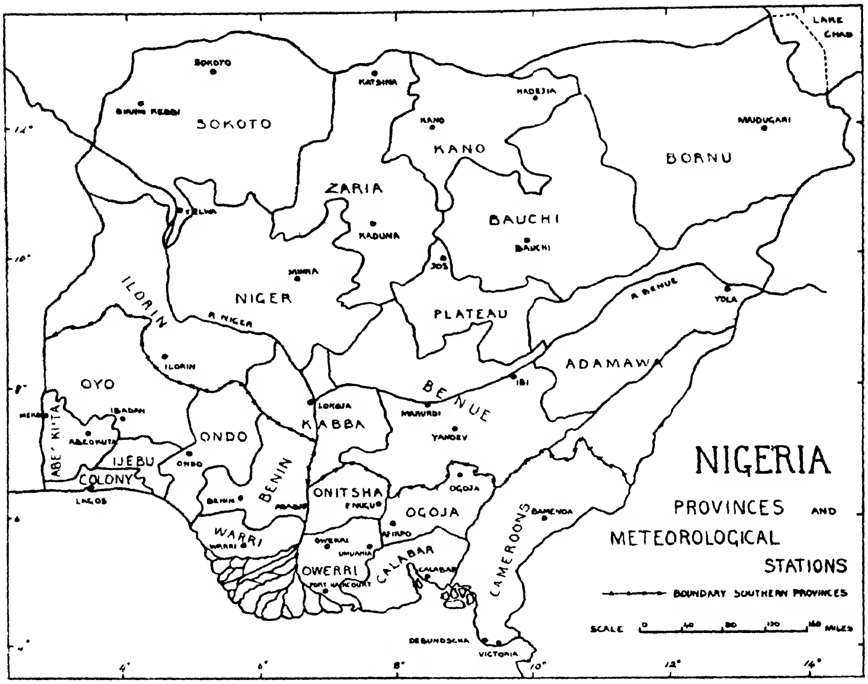

Fig. 1. Map of Nigeria.

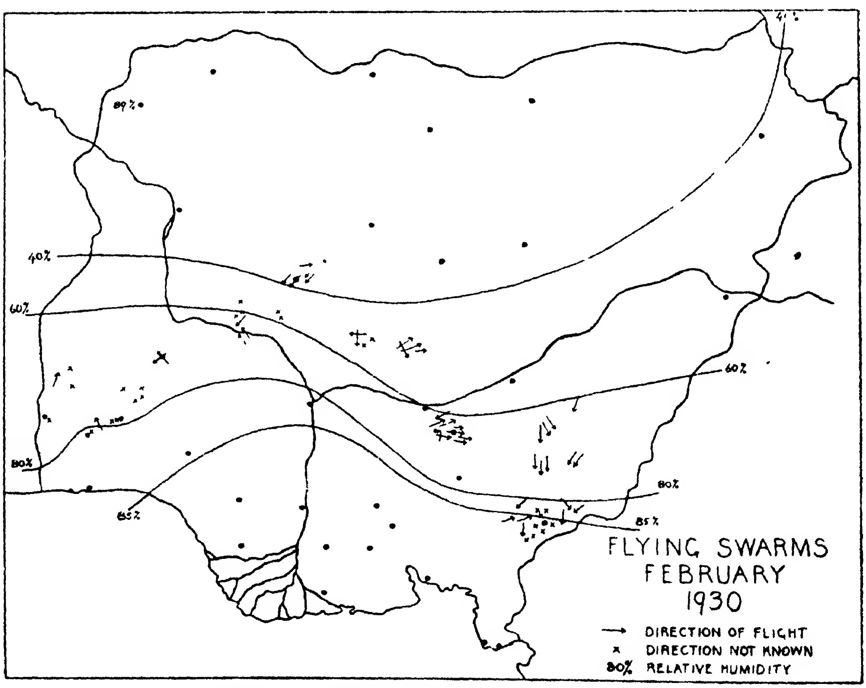

Fig. 2. Flying swarms, February 1930.

Meanwhile in April hoppers hatched in Abeokuta, Oyo and Benue Provinces. In May they hatched in Ilorin, Kabba, Niger, southern Zaria, Plateau, Bauchi, Adamawa, southern Sokoto and southern Kano. In June there were hoppers in all the Northern Provinces, though the infestation in Bornu was slight. The last of the hoppers of this generation became adult in July.

The F.5 adults appeared first in the south-west in early May. All the swarms of this generation migrated in a general east-north-easterly direction. A fresh intense invasion occurred in the north-west corner in May, June and July from the west. By the end of July there were few flying swarms in the country.

Period VII. July–December 1930.

The F.5 adults started to breed in the north-east corner in the vicinity of Lake Chad and hoppers became numerous in this area in August. In September hoppers reappeared in western Bornu, Kano and Zaria provinces, and in October in Sokoto, Adamawa, Plateau and Niger Provinces.

The F.6 adults first appeared near Chad in the middle of September, when the return migration into Nigeria commenced from the north-east. In October many swarms passed across the north of Nigeria to the west and there was a fair concentration in the centre of the country (Ilorin, Niger, Kabba, Plateau and Benue Provinces), where the swarms were moving generally to the south-west. By November they had migrated further south, especially down the eastern railway, near Enugu and Umuahia, and near Abeokuta and Ibadan. In December, although there were still a few swarms near the coast near Calabar and Lagos, there was a slight movement towards the north.

Period VIII. January–March 1931.

In February the swarms returned to the extreme south. In March a definite migration northwards commenced so that by April the Southern Provinces were practically free.

Period IX. Commencing April 1931.

The general movement towards the north continued and in April hoppers appeared in various parts of the Benue Province.

The Vegetation of Nigeria.

From the coast to the northern frontier we pass through belts of four of Shantz's types of vegetation :—

(1). Along the coast there is a thin strip of " mangrove forest."

(2). The limit of the " tropical rain forest " is roughly the line through Lagos, Abeokuta, Ibadan, Asaba and Ogoja.

(3). The broadest belt is that of the " high grass—low tree savanna," the northern limit of which passes through Yelwa, Kaduna and Bauchi. This belt is broken up by areas of " dry forest " and " mountain grass."

(4). The extreme north is covered by the " acacia—tall grass savanna " broken up by small areas of " dry forest " and " thorn forest."

The " acacia—desert grass savanna " approaches very close to the northern frontier especially near Lake Chad.

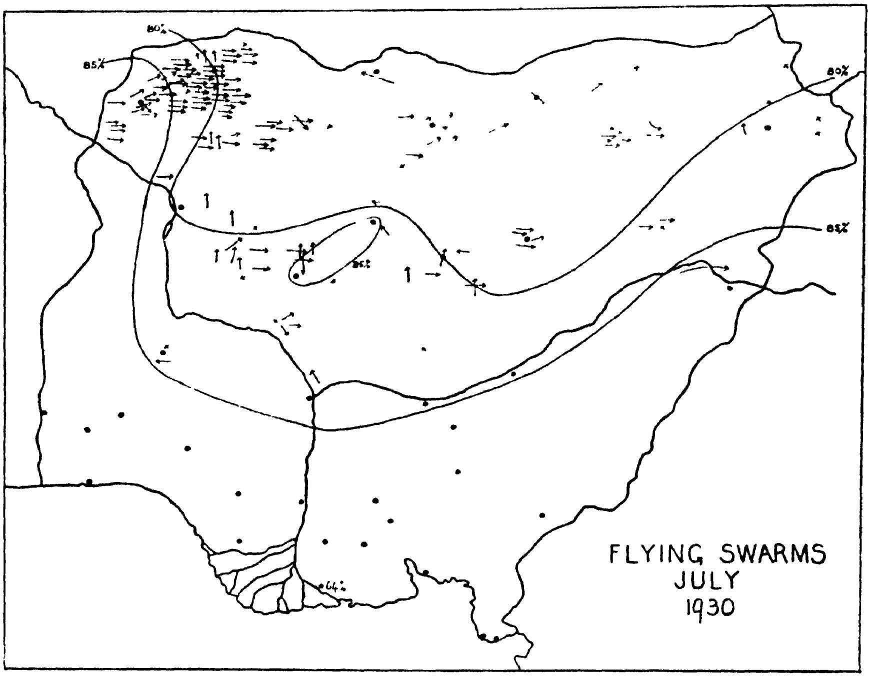

Fig. 3. Flying swarms, July 1930.

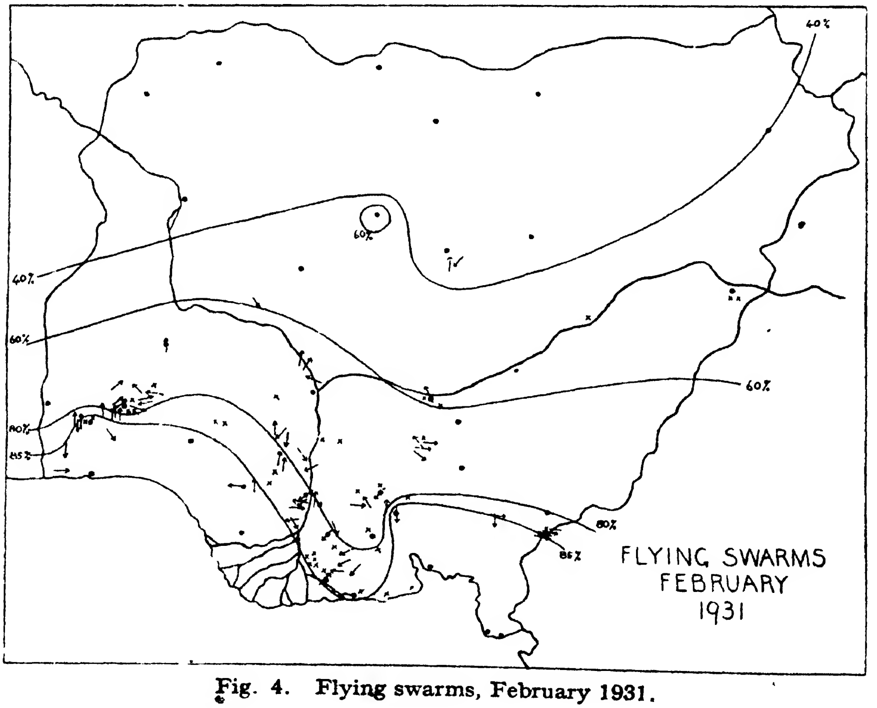

Fig. 4. Flying swarms, February 1931.

The Orography of Nigeria.

Roughly speaking there is a gradual slope, intersected by the valleys of the two great rivers, Niger and Benue, from the low-lying coastal region to the undulating plains of the extreme north, which are about 1,500 feet above sea-level. Near the centre of the country the land rises to a height of 4,000 to 6,000 feet, forming the Bauchi Plateau (Bauchi itself is 2,000 feet below the Plateau), upon which Jos (4,005 feet) is the only meteorological station. On the south-eastern frontier lie the Cameroon Mountains, rising to about 5,000 feet, and at the extreme south-east Cameroon Mountain (13,350 feet).

These mountains seem to have made very little impression upon the locust migrations. The Plateau has been very badly infested, and in June 1930, when the swarms were moving to the north-east, Jos seemed to lie on one of the main routes. Flights have also been common in the Cameroon Mountains.

The Climate of Nigeria.

The following is a brief summary of the cycle of the more important climatic elements in Nigeria with special reference to the period under review.

At the time of writing meteorological data covering the period are available from 35 stations fairly well distributed over the country, though it is unfortunate that there are no stations representing the open country of western Ilorin, western Oyo and western Abeokuta Provinces. These stations are classified in Table I according to the records taken.

TABLE I.

Meteorological Stations.

Rain Temperature Humidity Wind Pressure	Rain Temperature Humidity Wind	Rain Temperature Humidity	Rain
Calabar	Bauchi	Asaba	Debundscha
*Kano	Birnin Kebbi	Abeokuta	Meko
†Lagos	*Hadejia	Afikpo	
†Victoria	*Ibi	Bamenda	
	*Ilorin	Benin	
	*Jos	Enugu	
	*Kaduna	†Ibadan	
	Lokoja	Katsina	
	*Maidugari	‡Makurdi	
	*Sokoto	Ogoja	
	*Minna	Ondo	
	Yola	Owerri	
		Port Harcourt	
		Umuahia	
		Warri	
		†Yandev	
		Yelwa	

* Stations where velocity as well as direction of wind is usually given.
† Stations where humidity readings are taken twice daily.
‡ Humidity records considered unreliable.

The relative humidity is calculated from wet and dry bulb readings, and it is unfortunate that all but four stations only take these at 9 a.m., L.M.T. The mean calculated from both 9 a.m. and 3 p.m. readings would probably give better results.

Most of the records are taken from the returns published by the Surveyor General in the Nigerian Gazettes; those from Ilorin, Meko, Umuahia and Yandev, have been taken by officers of the Agricultural Department.

Rainfall.

The average annual rainfall varies from 356 inches at Debundscha in the south-east to 23 inches at Hadejia in the north.

There is a very definite dry season during the northern winter. This is shown in Table II, in which monthly figures for 1930 from representative stations are placed roughly in order from north to south. Average figures also show a marked short dry season in the Southern Provinces about August; in 1930 this occurred only in the south-west.

TABLE II.

Monthly Rainfall, 1930.

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Sokoto	...	...	...	...	2·2	5·2	9·3	8·3	4·1	...	...	...
Hadejia	...	...	...	...	0·5	1·7	6·2	4·4	1·5	0·4	...	...
Maidugari	...	...	...	...	0·6	1·3	10·5	9·6	4·2	1·5	...	...
Bauchi...	...	...	0·7	1·0	1·0	4·4	14·8	11·6	4·2	0·7	...	...
Kaduna	...	...	3·7	1·3	6·3	4·5	10·5	12·5	16·4	2·8	...	...
Yola	...	...	1·1	0·6	2·6	6·5	4·2	10·5	6·4	2·0	...	...
Ilorin	...	0·5	1·7	2·3	5·9	11·3	7·9	1·1	?	5·3	0·2	0·6
Makurdi	0·1	...	6·0	5·2	4·7	19·3	5·7	10·2	5·1	8·0	0·4	...
Ibadan	...	0·2	5·9	3·6	6·5	10·6	10·5	1·6	7·6	6·2	0·8	0·6
Ogoja	0·2	0·5	1·0	3·7	13·8	9·9	8·0	12·7	14·7	16·6	2·6	1·0
Abeokuta	3·8	...	4·2	4·6	7·2	4·6	10·0	3·2	2·7	7·2	1·8	0.7
Enugu	...	0·6	2·2	4·6	15·3	8·3	8·2	2·6	12·8	14·4	2·0	1·4
Lagos	1·4	2·2	3·3	5·0	8·6	13·3	18·4	0·7	2·5	12·5	1·9	1·7
Benin	0·7	2·8	1·7	4·4	5·2	7·0	15·1	14·6	18·2	12·5	3·6	2·3
Owerri	...	3·2	12·8	17·1	9·3	11·3	12·8	18·1	16·1	8·3	0·7	1·4
Calabar	0·6	1·7	10·5	12·7	15·8	11·2	13·2	17·1	13·1	11·5	7·0	1·2

Relative Humidity.

Table III shows how the mean relative humidity varies during the year at a few representative stations.

TABLE III.

Mean Relative Humidity Extremes, 1930.

Station	Minimum	Date	Maximum	Date
Sokoto	13	February	80	July
Hadejia	22	March	74	August
Kaduna	58	March	86	July
Yandev	66	December	91	August
Ibadan	74	January, February	88	July & October
Benin	86	February, March	93	December

During the 1929–30 dry season the driest month in the Southern Provinces was December, when the following stations recorded humidities over 80 per cent.—Afikpo, Asaba, Benin, Calabar, Ondo, Port Harcourt and Umuahia. In the north the driest month was February, when four stations recorded means under 20 per cent.—Jos, Kano, Katsina and Sokoto.

During the next dry season February was the driest month in the south, when the following stations recorded means over 80 per cent.—Abeokuta, Afikpo, Benin, Calabar, Ondo, Owerri, Port Harcourt and Warri (no records from Asaba). In the north the driest conditions obtained from December to March, and the following stations recorded means under 20 per cent. :—

December	*January*	*February*	*March*
Bauchi	Sokoto	Katsina	Hadejia
Katsina		Sokoto	Sokoto
Sokoto			

The main difference between the two seasons was in the advance of the high humidity towards the north in the western Provinces as will be discussed later.

Wind.

There are two prevailing winds in Nigeria, the south-west monsoon of the rainy season and the north-east wind or harmattan which blows during the dry season. The harmattan is associated with very low humidity, high day and low night temperatures, and a dust haze.

The winds during the period may be classified roughly as follows :—

December 1929.	General N.E. wind.
January 1930.	General N.E. wind in the Northern and S.W. in the Southern Provinces.
February–April.	Gradual spreading of the S.W. wind across the country from the south-west.
May–October.	General S.W. wind.
November–January 1931.	General N.E. wind in the Northern and S.W. in the Southern Provinces.
February–March.	Gradual spreading of the S.W. wind into central Nigeria.

In the north-west corner near Birnin Kebbi and Sokoto the winds were peculiar. They were from the north-east continuously from December 1929 to August 1930, when they commenced to change to the south-west and remained in this direction until the end of the period.

It will be seen from the above summary that during the second dry season the harmattan lifted before reaching the Southern Provinces.

Temperature.

The mean temperature only varies about 15° F., as is shown in Table IV. The annual march of temperature is of the equatorial type, with " two maxima following the two zenithal positions of the sun and two minima about the time of the solstices."[2] The first maximum is the highest and the winter minimum the lowest.

TABLE IV.

Mean Temperature Extremes, Dec. 1929 *to April* 1931.

Station	1st Min.	Date	1st Max.	Date	2nd Min.	Date	2nd Max.	Date
Sokoto	73	Dec.	91	Apr.	79	Aug.	85	Oct.
Bauchi	73	Jan.	86	Apr.	76	Aug.	81	Oct.–Nov.
Ilorin...	75	Dec.	87	Mar.	76	Aug.		—
Ibadan	78	Dec.	86	Mar.	75	Aug.	82	Dec.
Benin	77	Dec.	82	Feb.–May	73	Aug.	82	Dec.

There is a great difference between the actual maxima and minima, especially in the extreme north. During the period under review the highest maximum recorded was 113° at Hadejia in May 1930, and the lowest minimum 32° at Birnin Kebbi in March 1930 ; the latter figure is unusually low.

For the Northern Provinces the usual range is roughly 50°–105° and for the Southern Provinces 60°–100°. The maximum diurnal range occurs during the harmattan.

Atmospheric Pressure.

It has been suggested that there is a distinct relationship between the invasions of *Schistocerca gregaria*, Forsk., in Egypt, and movements of barometric depressions.[5] Unfortunately it is impossible to collect sufficient data to study this aspect of the problem in West Africa. The available data show only very slight pressure changes.

Relationship between the Behaviour of Swarms and Climate.

In attempting to correlate the behaviour of *Locusta migratorioides* with the climate we are not considering here the influence of the climate on individual locusts, or even on individual swarms, but upon the general mass movements of the swarms. In doing so we cannot expect to show any definite limits of dispersal owing to the local climatic variations and to the lack of detailed meteorological data ; we can only hope to study the general connection between climate and migration and to indicate what we may term the "climato-preferendum," *i.e.*, the climatic zone preferred by the locust.

A. Mass Movements.

Two climatic elements seem to be of primary importance in their direct effect upon migrations—humidity and wind.

(1). *Humidity.*

From the available information monthly maps have been prepared showing the isohyets and isohygros (lines of equal mean relative humidity) upon which were superimposed maps showing the distribution of the swarms. Three of these, February 1930, July 1930, and February 1931, showing only the more important isohygros and the swarms are reproduced in charts 2, 3 and 4. The contours can only be regarded as a rough indication of the humidity gradient, and it should be remembered that these represent the means for the month, while the swarms are represented by their actual positions throughout the month.

In studying the distribution of mean humidity and swarms it was soon apparent that there was a close relationship. The swarms avoid both extremes of humidity and remain with very few exceptions within the belt limited by the 40 per cent. and 85 per cent. isohygros, and move up and down Nigeria, that is across the vegetation belts, according to the march of the humidity.

The writer has previously suggested[3,4] that the southern limit of migration corresponds with the northern limit of the tropical rain forest, though it was pointed out that this belt is sometimes penetrated during the dry season. Chevalier[1] confirmed this general hypothesis for French West Africa.

The limit of the tropical rain forest corresponds closely with the dry season southern limit of the 80 per cent. isohygro, but that the humidity and not the vegetation is the limiting factor is indicated by the movement of the swarms during the second dry season in the south-eastern Provinces.

By October 1930, the swarms had only gone as far south as Makurdi and Lokoja. In November they passed down the eastern railway as far as Aba with a few swarms further east between Ogoja and Calabar. During the same month there was a dip of the 85 per cent. isohygro down the railway as far south as Port Harcourt ; Ogoja,

Umuahia and Calabar were just outside. In December, although a few swarms were reported near Calabar, most had moved slightly north to just south of Enugu and at the same time the isohygro moved north to between Enugu and Owerri. In January there were no swarms near the coast : there were a few south of Enugu but most had moved yet further north. There was now no southern dip of the isohygro and Enugu was near the southern limit. In February the swarms moved right down to the coast again near Port Harcourt and Calabar, and again we find the isohygro dipping down to the coast and including Port Harcourt (see fig. 4). In March the swarms moved up with the isohygro to the Enugu area. In April the humidity was much the same ; near the coast there was a slight decrease, while inland there was a slight increase in the humidity. The swarms had moved out of the Southern Provinces, and Enugu (79 per cent.) was the only station recording humidity below 80 per cent. The humidities for this area are summarised in Table V.

TABLE V.

Mean Humidities, S.E. Nigeria, 1930–31.

Month	Afikpo	Calabar	Enugu	Ogoja	Owerri	P.Harcourt	Umuahia*
October ...	78	89	84	89	86	86	93
November	92	89	73	86	80	79	89
December ...	92	89	78	86	87	87	89
January ...	93	89	80	83	87	88	92
February ...	93	89	72	77	81	84	79
March ...	93	88	77	79	86	86	81
April ...	93	86	79	86	85	82	83

* Readings taken at 8.30 a.m., L.M.T.

Further evidence of the connection between the humidity and the general movement of swarms is given by the comparison of the advance of the swarms from the south-west into central and northern Nigeria at the close of the two dry seasons.

In March 1930, only Ondo, Benin, Warri and Asaba, recorded humidities over 85 per cent., and swarms were present more or less throughout the area immediately north of the isohygro, *i.e.*, Abeokuta, Oyo, Ilorin and Kabba Provinces.

In March 1931, the isohygro was further north in the west but dipped south near the Niger. Abeokuta, Ondo, Benin, and Warri, recorded over 85 per cent. (no record from Asaba). This year there were no swarms in Abeokuta Province, though there were a few in southern Oyo ; they were present in Ilorin, northern Ondo and south-east Benin Provinces.

In April 1930, the isohygro ran more or less through Abeokuta, Ibadan and Lokoja. Swarms were present in Abeokuta, Oyo, Ilorin and Kabba Provinces.

In April 1931, the isohygro was further north and the swarms had moved considerably further north ; except for two swarms in Oyo there were none in the Southern Provinces.

TABLE VI.

Mean Humidities, S.W. Nigeria.

	1930		1931	
	March	April	March	April
Abeokuta	83	91	93	95
Ibadan	84	81	79	85
*Ilorin	72	72	76	77
Ondo	86	90	94	93
Benin	86	91	88	87

Readings taken at 8.18 a.m., L.M.T.

Whereas in 1930 there were innumerable hopper bands in Abeokuta and Oyo Provinces, in 1931 there were none in Abeokuta and only an isolated outbreak on the Oyo—Ilorin boundary near Ilorin.

After the first breeding season, when adults of the next generation were beginning to appear, the position is rather obscured because some of the new swarms matured in the 85–100 per cent. humidity belt. As soon as their migratory flights commenced, however, they moved north of the 85 per cent. isohygro.

August and September 1930 were the most humid months, when only the following Provinces lay north of the 85 per cent. line: Sokoto, northern Niger, Zaria, Kano, northern Plateau, Bauchi and Bornu—and swarms were practically confined to this area.

In October the humidity retreated south so that the 85 per cent. isohygro more or less coincided with the course of the Niger and Benue Rivers meeting at Lokoja. The swarms also turned and moved south to about this level.

The northern arid limit of the dispersal zone is more difficult to place because, during the wet season, it lies outside Nigeria, the humidity gradient is slight, and there are comparatively few meteorological stations in the north.

During the first few months of the infestation, up to April 1930, the swarms had not had time to cover the whole zone lying between the 85 per cent. and 40 per cent. isohygros. From then more or less the whole of this belt lying within Nigeria was infested. The majority of swarms kept within the 60–80 per cent. humidity limits.

From December 1929 to April 1930, the swarms moved into northern Nigeria behind the 40 per cent. isohygro. From May to October the humidity was above 40 per cent. throughout the country. From November to March the swarms retreated from the north ahead of the isohygro, though some of the F.6 adults matured behind this limit. In April the isohygro again moved north with the swarms following close behind.

Summarising the effect of humidity upon the migrations we find there is considerable evidence to show that the area of dispersal is limited by the humidity factor. With very few exceptions swarms remain within a belt limited by the 40 per cent. and 85 per cent. contours (isohygros) of the humidity gradient. This zone we may term the hygro-preferendum.

(2). *Wind.*

(Directions of migrations are given as that towards which the swarms are moving, while the direction of the winds are given as that from which they are blowing.)

In the previous paper,[4] it was suggested that the main migrations seemed to be affected by, and agree with, the prevailing winds. In a table given there it was seen that out of 23 main migrations only one was directly opposed to the normal prevailing wind. This exception was the southerly migration up the Nile through Uganda. The Nigerian migrations are now studied in greater detail.

In the first place it may be pointed out that there is no evidence of flights at any high altitude where the direction and force of the wind might differ to any extent from what is observed from the ground.

The original eastern migration into south-western Nigeria from Dahomey, in December 1929, was opposed to the north-east wind recorded at Lagos and Ilorin, while the wind at Ibadan was N.N.W. In January the prevailing winds at Lagos were N.E. and S.W., at Ibadan N.W., and at Ilorin N.E.

By February the prevailing winds of the Southern Provinces and as far north as Ilorin and Lokoja had changed to the S.W., so that the gradual spreading of swarms towards the north-east at this time was aided by the wind.

From May to July there was the big migration from the west into north-western Nigeria, when the swarms moved up the Sokoto River past Birnin Kebbi and Sokoto. The winds were as follows :—

May ...	Birnin Kebbi ...	N. ...	Velocity 3·2 m.p.h.
	Sokoto	N.E. ...	
June ...	Birnin Kebbi ...	N.E. ...	„ 3·0 „
	Sokoto ...	N.E. ...	
July ...	Birnin Kebbi ...	N.E. ...	„ 3·1 „
	Sokoto	N.E. ...	

The return migration from the north-east began in Chad at the end of September, coinciding with the turn of the humidity towards the south. At Maidugari the wind did not change from the S.W. (velocity 0·5 in October) to the N.E. until November, when the velocity was 1·6.

Calabar is the only station recording wind direction in the south-eastern Provinces. As we have seen, the swarms reached that locality from the north in November, when the wind was S.W. In December and January the swarms moved slightly northwards ; in December the wind was still S.W., but in January when this migration was most marked it had changed to the N. In February the N. wind assisted the return to the coast. In March the swarms moved north again though the wind was still N. changing to the S.W. in April.

The second general north-easterly migration from the south-western Provinces was again assisted by the S.W. wind.

From the scanty information available it seems therefore that the wind is not of primary importance in determining the general direction of migrations. Two main invasions were at an angle of about 135° against the wind, and in the second of these the average wind velocity was 3·1 m.p.h. The reversal of the migrations in the north-east, in September and October 1930, coincided with humidity changes and not with the change of the wind, though the velocity of the contrary wind was only 0·5 m.p.h. On the other hand, within the hygro-preferendum, the dispersal of the swarms, especially along the humidity gradient, is probably influenced by the winds. Thus during the primary spread of swarms through Nigeria the general northward movement was probably due to the humidity gradient, while the tendency to migrate to the east was probably due to the prevailing winds. The same holds true for the reverse migration during the latter part of 1930, when the harmattan carried the swarms to the west, while the humidity brought them south.

(3) *Precipitation.*

The annual cycles of humidity and precipitation are closely related and similar in their advance and retreat across the country, but there is no evidence of direct connection between the march of the rainfall and the movements of the swarms.

(4) *Temperature.*

There is no apparent relationship between temperature and the distribution of swarms.

B. Breeding.

It has been found that under West African conditions there are normally two breeding seasons a year : one at the beginning and one towards the end of the wet season.

It has already been suggested[4] that the dry season causes an adult diapause when the development of the gonads is arrested. It was shown that at the end of the dry season oviposition occurred shortly after the first rains, and during the wet season sexual maturity was reached after quite a short interval.

The work on the Migratory Locust in Russia has shown that temperature and humidity are important limiting factors as regards both dispersal and breeding. Predtechenskiĭ[6] has found that breeding is impossible where the mean relative humidity exceeds 73 per cent., even if the temperature is within the optimum range. Predtechenskiĭ's humidity records are probably the means of both 9 a.m. and 3 p.m. daily readings.

First Breeding Season.

In working on the relationship between the commencement of the rains and breeding it has been found that the effect of the precipitation is best expressed as monthly degrees of wetness rather than total monthly rainfall. This is calculated as follows :—

$$\text{M.D.W.} = \frac{R \times D}{10}$$

where, R = total monthly rainfall, D = number of days when more than 0·01 in. rain has fallen, M.D.W. = monthly degree of wetness.

Unfortunately there have been remarkably few actual observations of oviposition, and the best available index of the commencement of breeding has been the appearance of hoppers. There is no definite evidence of any diapause during the egg stage, and there is little doubt that in nearly all cases hatching takes place after about 12 or 13 days.

Since humidity and precipitation seemed the most likely climatic factors to affect sexual maturity, they were studied by means of a type of climatograph in which the mean relative humidity and degree of wetness for each month are plotted along the two ordinates and the points joined up in order of the months. The data employed are the actual records for each month of the infestation and not the monthly means over a period of years, as is more usual in this type of work.

Climatographs were drawn for each meteorological station and were studied in relation to the occurrence of hoppers in the locality. Five of these are reproduced figs. 5–8, with graphical representations of the occurrence of both flying swarms and hoppers. From these a rough indication of the connection between the time of breeding and the climatic elements is obtained. The apparent optimum breeding conditions are shown by the superimposed lines indicating that breeding is likely to commence as soon as the monthly degree of wetness rises above 2, so long as the humidity is not less than 65 per cent. and not more than 80 per cent.

The records of the meteorological stations usually show the average climatic conditions of the locality, the most obvious exceptions being the river stations, but it should be remembered that if the readings do not fall quite within the optimum, it is by no means impossible that optimum conditions have obtained in the neighbourhood. Furthermore we are dealing with a nomadic insect, and it is possible that a swarm may pass through optimum conditions, thereby having the mechanism of sexual maturity released, though by the time oviposition takes place a locality may be reached where the conditions are not so favourable. In general, however, this type of climatograph does indicate when breeding is likely to occur in any given locality.

The results of the study of the data from the individual stations where breeding took place are summarised below. Details of the infestation near Bamenda are too indefinite for analysis.

Abeokuta.—This station gave the least satisfactory results. Abeokuta itself lies on the edge of the forest and therefore on a steep climatic gradient. It also lay near the limit of the dispersal zone, and though there were many hoppers in the Province, most were found to the west and north of the town in the high grass—low

tree savanna. The climatograph shows that conditions were favourable for flying swarms only from December 1929 to March 1930, and that optimum breeding conditions never obtained. Swarms were actually present from December 1929 to May 1930, the latter swarms having been bred locally, and again from November 1930 to February 1931. Hoppers appeared in April 1930, and the Province was clear by the middle of May.

Bauchi.—Conditions were favourable for flying swarms in January, from March to November 1930, and from March 1931. Swarms did not reach the Province until mid-March 1930, and it was clear early in August. Swarms appeared again in September and remained until November. In 1931 they arrived at the beginning of March. Breeding conditions came within the optimum at the end of May and hoppers appeared on May 7th.

Birnin Kebbi.—Conditions were favourable for flying swarms from March to October 1930 ; no records were taken in March or April 1931. Swarms arrived in late April and were present until early November, the later swarms being locally bred. Breeding conditions probably came within the optimum in early May, but no records were taken in April or May 1930. Hoppers first appeared on 2nd June.

Hadejia.—Conditions were favourable for flying swarms from early May to the end of October and again in December (55 per cent. humidity). Swarms arrived in mid-May and were present until the end of September. Optimum breeding conditions were reached in late June and hoppers appeared on 4th June.

Ibadan.—Conditions were favourable for flying swarms all 1930, except for late June, July and October, and until April 1931. Swarms were present in the locality until late May and from the end of October to mid-March 1931.

The climatograph for this station is very erratic, passing across the optimum breeding conditions in March and August and with the April point just outside and the May point upon the humid limit. Breeding commenced in mid-April with 81 per cent. humidity and 2·9 degrees wetness. Although conditions were favourable for flying swarms in August, the locality was isolated from the main area of infestation by a belt of high humidity. No breeding occurred very near Ibadan. This station is near the forest limit.

Ibi.—Conditions were favourable for flying swarms from January (44 per cent. humidity) to the end of July, except for June (88 per cent. humidity), and from late October to the end of the period. Ibi is towards the east and swarms did not reach there until April, remaining to June ; they were present again from October to January. Optimum breeding conditions were reached in mid-April and hoppers appeared on 14th April. This is a river station and the recorded humidities are probably above the average for the district.

Ilorin (fig. 8).—Conditions were favourable for flying swarms throughout the period. Swarms were present from December to early June and from late October to the end of the period. Optimum breeding conditions were reached in mid-April and hoppers appeared at the end of April. The meteorological readings at this station are taken at 8.18 a.m., L.M.T.

Jos (fig. 5).—Conditions were favourable for flying swarms from early April to the beginning of November and again from April 1931. Swarms were present from the end of March to the beginning of November and reappeared at the end of March 1931. Optimum breeding conditions were reached about the end of April and hoppers appeared on 8th May.

Kaduna.—Conditions were favourable for flying swarms the whole of the period. Swarms were present from April 1930 to January 1931, and from April 1931. Optimum breeding conditions were reached in mid-May and hoppers appeared towards the end of May.

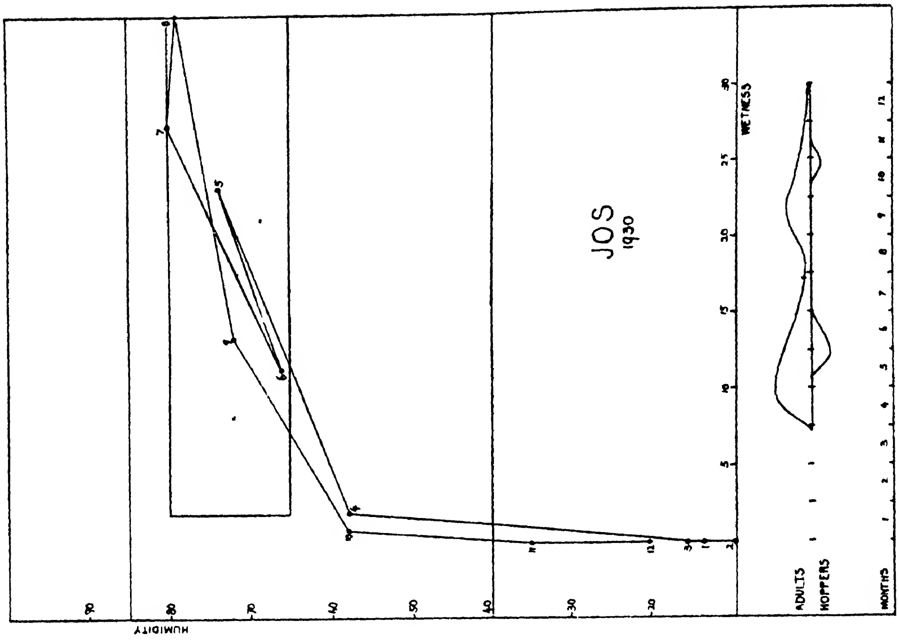

Fig. 5. Climatograph of Jos.

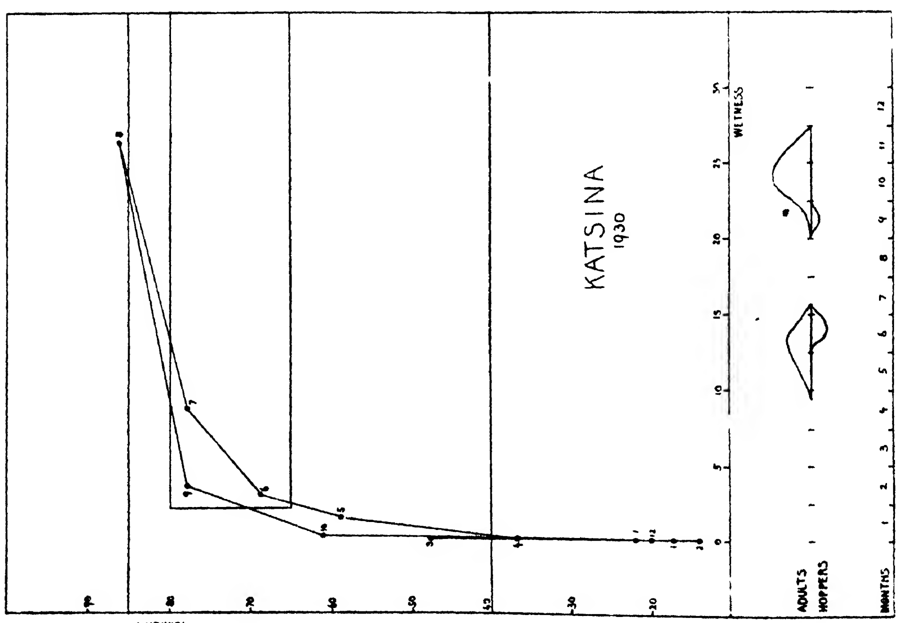

Fig. 6. Climatograph of Katsina.

Kano.—Conditions were favourable for flying swarms from mid-April to the beginning of November. Swarms were present from the middle of April to November (later swarms locally bred). Optimum breeding conditions were reached in early June and hoppers appeared on 1st June.

Katsina (fig. 6).—Conditions were favourable for flying swarms in March and from about the end of April to the end of October. Swarms were present from the end of April to July and from the beginning of September to early November (later swarms locally bred). Optimum breeding conditions were reached at the beginning of June and hoppers appeared in mid-June.

Lokoja.—The records show humidities of 74–86 per cent. obtaining throughout the period, but this is another river station and is probably not typical of the region. Swarms were present from the end of December to early July and from October to the end of the period. Optimum breeding conditions were reached in April and hoppers appeared in mid-May.

Maidugari.—Conditions were favourable for flying swarms from December 1929 to February 1930, and from May to the end of the period, except for March 1931. The humidity was, however, only just above the lower limit from November to February and in April. Swarms were present from the end of April to the end of October 1930. Optimum breeding conditions were reached about the middle of June and hoppers appeared then.

Minna.—Conditions were favourable for flying swarms from March to mid-June and from mid-September to the end of the period. Swarms were present from the beginning of February throughout the period. The humidity never rose above 88 per cent. Optimum breeding conditions were reached at the end of April and hoppers appeared on 2nd May.

Sokoto.—Conditions were favourable for flying swarms from the beginning of May to mid-October. Swarms were present from early May to the end of July and again in October. Optimum breeding conditions were reached in mid-June and hoppers appeared on 13th June.

Yandev (fig. 7).—Conditions were favourable for flying swarms from December 1929 to the end of May, and from the end of October to the end of the period. Swarms were present from the end of January to the beginning of June and from the end of October to the end of the period. Optimum breeding conditions were reached in early April and hoppers appeared on 12th April. In 1931 optimum breeding conditions were reached in mid-April and hoppers appeared on 26th April. The meteorological readings are taken at this station at 8.36 a.m., L.M.T.

Yelwa.—Conditions were favourable for flying swarms from March to October at least (November and December, no records) and in January. Swarms were present from mid-April to mid-September, and appeared again in April 1931, when the humidity was only 22 per cent.* Optimum breeding conditions were reached in mid-May but we have no details of the hopper infestation in this area.

Yola.—Conditions were favourable for flying swarms throughout the period except from the middle of June to the middle of September. Swarms were present from the end of April to the beginning of July and from September to the end of the period. Optimum breeding conditions were reached about the end of May and hoppers appeared on 21st May.

Optimum breeding conditions obtained at two other stations where no breeding occurred. At Owerri in April when no swarms were near and at Port Harcourt in July when also no swarms were near. In all other stations conditions were never favourable and no breeding was recorded.

*Record doubtful.

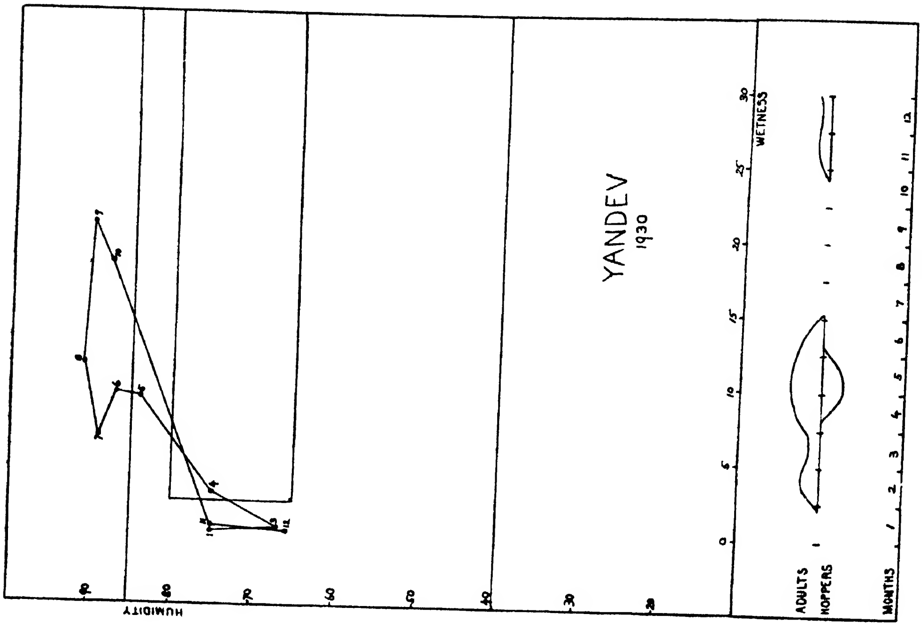

Fig. 7. Climatograph of Yandev.

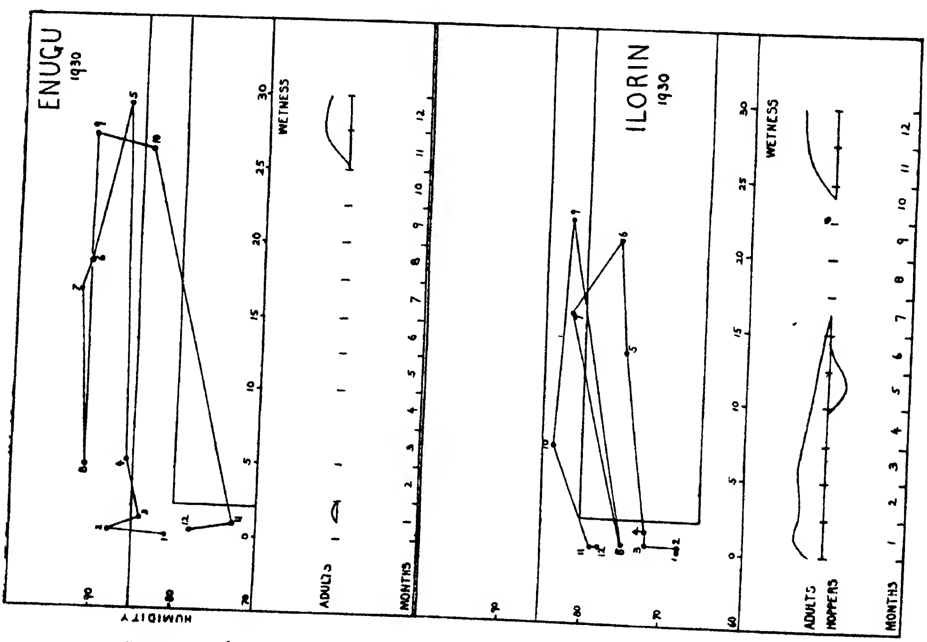

Fig. 8. Climatographs of Enugu (above) and Ilorin (below).

Second (1930) *Breeding Season.*

The commencement of the second breeding season may depend on climatic conditions, or it may follow after a definite interval after the locusts become adult, or, more probably, it may depend on a combination of the climatic and time factors. Rainfall may be less important than at the commencement of the first breeding season as the ground would probably be still moist.

In Nigeria the first adults of the F.5 generation matured in early May in the south-west. The first hoppers of the next generation hatched at the beginning of August near Chad; they may have been earlier to the east of the lake. This gives a period of about eleven weeks from becoming adult to oviposition. The last adults of the F.5 generation matured about the middle of July in the north and the last breeding apparently took place about the beginning of November, giving a period of about 15 weeks.

During the second breeding season breeding occurred in the locality of only 12 meteorological stations. These may be classified into: (*a*) those where, during the interval between the breeding seasons, the humidity rose markedly above 80 per cent.; and (*b*) those where it did not.

Near the stations in class (*a*) hoppers appeared as follows:—

Birnin Kebbi, in late November, the humidity having dropped from 84 per cent. to 66 per cent. and the degree of wetness from 8·6 to 0·1 in October and November.

Katsina, in early September when the humidity approached the 80 per cent. limit; degree of wetness about 12.

Minna, in October shortly after the humidity had dropped below 80 per cent.; degree of wetness about 2.

Yola, in early October when the humidity dropped from 86 per cent. in September to 55 per cent. in October; degree of wetness about 5.

Thus for the few stations where the humidity rose above the apparent optimum, breeding did not commence before the optimum was again reached. It seems likely therefore that high as well as low humidity may cause an adult diapause. The commencement seemed independent of rainfall.

For the stations in class (*b*) we find hoppers appeared as follows:—

Bauchi, in early October with humidity about 70 per cent. and degree of wetness about 2.

Hadejia, in mid-August with humidity 74 per cent. and degree of wetness 4·4.

Jos, in mid-October when the humidity (58 per cent.) had just fallen below the lower optimum limit (September 72 per cent., October 58 per cent.); degree of wetness 0·9.

Kaduna, in mid-October with humidity 74 per cent. and degree of wetness 1·9.

Kano, in mid-September with humidity 76 per cent. and degree of wetness 6·3.

Maidugari, in early August when the humidity (82 per cent.) was just above the optimum; degree of wetness 13·5.

Sokoto, in early October when the humidity had fallen below the optimum (August 79 per cent., September 64 per cent., October 56 per cent.); degree of wetness 0.

There now remain those localities where no second breeding was reported. These may be classified into: (*a*) those where climatic conditions were apparently suitable; and (*b*) those where they were not.

(*a*) These localities may be sub-divided into (1) those where swarms were present when the climate was suitable—the swarms may have been either F.5 or F.6—and (2) where no swarms were present.

(1) *Lokoja*, humidity only just above the optimum limit in October when F.5 swarms were present.

Port Harcourt, conditions suitable and swarms present in November—all seem to have been F.6.

Yandev, conditions suitable and swarms containing F.5 and F.6 adults present in October and early November.

Yelwa, conditions suitable in September and early October ; swarms, presumably F.5, present in September. No information about hoppers in this area.

(2) *Afikpo*, conditions suitable in October.

Enugu, conditions suitable in October.

(*b*) Abeokuta, Asaba, Benin, Calabar, Ibadan, Ilorin, Ogoja, Ondo, Owerri and Warri.

The first adults of the F.6 generation appeared in Chad in mid-September. As we have seen, under fairly suitable climatic conditions, the minimum period from becoming adult to oviposition is about eleven weeks. Therefore we should not expect this generation to breed again until the beginning of December, by which time the climatic conditions were out of the optimum in all stations. There were, however, a few isolated hopper outbreaks during the dry season, and it is probable that local climatic optima permitted this breeding or rather did not prevent sexual maturation.

One may presume that there is a limit to the duration of the adult diapause. When this limit is approached it is possible that the swarms concentrate even more within the 65–80 per cent. humidity belt. Such may be the explanation of the movement of the swarms out of the south-eastern Provinces in 1931 somewhat ahead of the advance of the apparent southern limit of dispersal.

When swarms are unable to reach suitable climatic conditions death may occur. During the early part of 1931 several reports were received of high mortality amongst swarms. As no specimens were examined until some time after death, it is quite impossible to say whether parasites were the cause of death. It seems as likely that the locusts were unable to live through the dry season.

On 15th February locusts were observed to fall to the ground in a dying condition from a swarm circling near Aba in Owerri Province. The humidity was close to the humid limit of the optimum breeding conditions, but the rains had not commenced.

On 23rd February hundreds of dead were picked up after a swarm had passed Oshogbo (between Ibadan and Ilorin). The humidity was suitable for breeding, but the rains had not begun.

On 25th February numbers of locusts were seen to fall to the ground in moribund conditions from a low-flying swarm south of Jos. This swarm was well isolated from the main infestation (see fig. 4) and the humidity at Jos was only 25 per cent.

In February dead locusts were picked up after a swarm had passed Badagri (on the coast west of Lagos). The humidity is not known, but the rains had not begun.

On 30th April a swarm settled in a swamp at Giru, between Yelwa and Birnin Kebbi, and all were found dead the following morning. No meteorological records were taken at Birnin Kebbi at this time ; at Yelwa the degree of wetness had reached 2·1, but the humidity is given as 22 per cent , though such a low percentage at this time of the year is very questionable.

On 9th May individuals were found dropping dead off trees at Maidugari. This swarm contained both *L. migratorioides* and *Schistocerca gregaria*. The humidity was low (44 per cent. in April and 51 per cent. in May) and the rains had not begun.

About 20th May a considerable number of old F.6 adults died in north-western Bauchi Province. These probably died naturally after breeding.

The adults of this generation first appeared in mid-September and began to die in mid-February, so that it appears that the limit of adult longevity through the dry season is about 22 weeks.

Summary and Conclusion.

The locust infestation in Nigeria, from December 1929 to April 1931, is studied in relation to the climate and the following preliminary conclusions are made.

1. Humidity, precipitation and wind are the relevant climatic elements. Temperature does not seem of importance.

2. It is considered that the area of dispersal is limited by the humidity factor. With very few exceptions swarms remain where the mean relative humidity (9 a.m., L.M.T.) is not more than 85 per cent. and not less than 40 per cent., while most swarms are found where the humidity is from 60 per cent. to 80 per cent.

3. This humidity belt is similar to the area covered by three main types of vegetation and the swarms move across the belt according to the humidity changes.

4. Movement along the belt is largely caused by the prevailing wind.

5. Breeding does not commence after the dry season until the humidity rises to 60 per cent. and the degree of wetness, calculated from the monthly rainfall, reaches 2. Breeding does not occur if the humidity is above 80 per cent.

6. Through the dry season the adults seem unable to live much more than 22 weeks, and if optimum breeding conditions are not reached within that period death may occur.

7. Breeding towards the end of the rainy season follows some 11 to 15 weeks after the locusts become adult, so long as the humidity is not more than 80 per cent., and high humidity may cause a diapause.

8. Suitable local conditions during the dry season may allow a third breeding season.

These conclusions may be utilised in the following ways:—

1. To delimit the total area likely to be infested.
2. To forecast when the different zones will be infested by flying swarms.
3. To forecast whether and when breeding is likely to occur in each locality.
4. To check whether unidentified swarms were of this species of locust.
5. To test the possibility of one suspected breeding ground having been infested from another.

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NOTES ON THE BREEDING OF *NOMADACRIS SEPTEMFASCIATA* (ORTH., ACRID.) ON THE SHORES OF LAKE CHAD.

By Owen B. Lean, B.Sc., D.I.C., F.E.S.

The writer was engaged on control measures against hopper bands of the Migratory Locust, *Locusta migratorioides*, R. & F., along the western (Nigerian) shore of Lake Chad from the middle of August to the end of October 1930.

On arrival in Chad it was found that hoppers of another locust were swarming and causing considerable damage to the cereal crops. The adults of these hoppers were later identified by Mr. B. P. Uvarov as *Nomadacris septemfasciata*, Serv., the Red Locust of South East Africa. Hitherto this species has not been recorded in the swarming phase in western equatorial Africa, little has been known of its breeding habits and the hoppers have not been described.

No parent swarms had been reported and no oviposition was observed. Hatching apparently commenced about the middle of July and went on until the middle of August. The rainy season lasts from about June to September.

Habitat.

Hopper bands were present all down the very indefinite south-western shore of the lake. They were found more or less confined to the " marsh grass " association and were not found in the " orchard " or " thorn " associations further back from the lake, as were the hoppers of *migratorioides*. They were frequently observed on the grasses where the ground was submerged.

Behaviour.

The hoppers form definite bands, but these are not so dense as the bands of *migratorioides*, neither were the mass migrations so marked. Older hoppers were found scattered in the grass land, and there seemed to be a tendency for the bands to become more diffuse during the later hopper instars.

The hoppers were more active than those of *migratorioides* ; they were more easily scared by noises and consequently were much easier to destroy by driving into trenches.

Food-plants.

The hoppers and the newly emerged adults seem to feed entirely on Gramineae.

Life-history.

This was not worked out in detail. The first adults appeared at the end of September, so that the duration of the hopper stages seems to be longer than for *migratorioides* and is probably about seven to eight weeks.

Hoppers.

The hoppers are very characteristic and do not change in their general coloration throughout development. They are characterised by their general pale green colour, light reddish-brown head and the black dorsal stripe.

Description of 4th instar hopper.—Head and pronotum pale green. Face light red-brown, rather oblique ; long black triangular mark pointing down from base of eye. Antennae dark brown, lighter at base ; 25-jointed. Pronotum with very

definite black dorsal stripe, which is continued down the abdomen; sides spotted with dark brown. Prosternum with spine directed backwards. Wing rudiments pale. First two pairs of legs light green spotted with brown; hind femur with black stripe two-thirds towards distal end. Abdomen pale green, sides spotted with black. Length about 22 mm.

Behaviour of Adults.

Shortly after the final ecydsis the adults caused very considerable damage to the maize farms where the cobs were nearly ripe. Besides eating the leaves they destroyed the sheaths around the cobs, eat into the grain and sometimes devoured almost the entire cob, working from the tip downwards.

The writer never observed a regular flight of these locusts. When a swarm was disturbed the individuals either flew away a few yards like a grasshopper or the swarm rose and circled without moving far. All the swarms observed were however quite young and other locust control officers reported definite migratory flights in October, when swarms were seen almost daily passing down the coast of the lake from the north-west to the south-east. Specimens taken from some of these swarms were said to be *Nomadacris septemfasciata*, Serv.

At present we know little of the annual life-cycle of this locust in the Chad area or of the subsequent movement of the adults bred there, but it is hoped that the study will be continued.

15th June 1931.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st July and 30th September, 1931, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance:—

ACME FLOORING AND PAVING CO. (1904) LTD.:—10 Coleoptera; from England.

Mr. T. J. ANDERSON, Government Entomologist:—44 Coccinellidae; from Kenya Colony.

Messrs. ANNING & COBB:—9 Coleoptera and 4 larvae; from New Zealand and Australia.

Mr. D. J. ATKINSON:—31 Diptera and 133 Parasitic Hymenoptera; from Burma.

Dr. T. V. RAMAKRISHNA AYYAR, Assistant Entomologist:—14 Diptera, 2 Parasitic Hymenoptera, 4 other Hymenoptera, 60 Coleoptera, 10 Lepidoptera, 12 Rhynchota, and 8 Orthoptera; from South India.

Mr. J. BALFOUR-BROWNE:—166 Hymenoptera, 321 Rhynchota, 57 Orthoptera, 5 Dermaptera, and 17 Odonata; from Madeira and the Azores.

Mr. A. H. BASTIN:—1 Blattid; from England.

DR. P. A. BUXTON:—102 Orthoptera; from Switzerland.

Mr. C. P. CASTELL:—53 Parasitic Hymenoptera; from England.

CHIEF ENTOMOLOGIST, PRETORIA:—4 Trypetidae, 45 Parasitic Hymenoptera, and 83 Coleoptera; from South Africa.

Mr. R. N. CHRYSTAL:—15 Parasitic Hymenoptera; from England.

Mr. L. D. CLEARE, Junr., Government Entomologist:—12 Parasitic Hymenoptera, 112 other Hymenoptera, 2 Coleoptera, 178 Lepidoptera, 6 species of Coccidae, 4 species of Aphidae, 1 species of Aleurodidae, 61 other Rhynchota, 4 Orthoptera, and 4 Planipennia; from British Guiana.

Prof. T. D. A. COCKERELL:—2 Culicidae, 127 other Diptera, 22 Parasitic Hymenoptera, 495 other Hymenoptera, 92 Coleoptera, 36 Lepidoptera, 2 species of Coccidae, 2 species of Aphidae, 123 other Rhynchota, 110 Orthoptera, 15 Odonata, and 8 Spiders; from Angola and the Belgian Congo.

Mr. G. H. CORBETT, Government Entomologist:—28 Diptera, 32 Parasitic Hymenoptera, 16 other Hymenoptera, 131 Colepotera, 99 Lepidoptera, 100 Thysanoptera, 3 species of Coccidae, 6 species of Aphidae, 27 other Rhynchota, 8 Orthoptera, and 2 Slugs; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI:—1,980 Coleoptera; from Kenya Colony.

Mr. A. CUTHBERTSON, Assistant Entomologist:—40 Diptera, 9 Parasitic Hymenoptera, 2 Coleoptera, and 4 Lepidoptera; from Southern Rhodesia.

Miss R. M. DAVENPORT:—1 species of Aphidae and 4 other Rhynchota; from Iceland.

DIRECTOR, INSTITUTO SEIRO-VACCINOGENO, MERCA:—6 *Glossina*; from the Italian Somaliland.

DIRECTOR OF AGRICULTURE, GAMBIA:—6 Orthoptera; from the Gambia.

DIRECTOR OF AGRICULTURE, REDUIT:—1 species of Aphidae; from Mauritius.

DIRECTOR OF VETERINARY SERVICES, PRETORIA:—2 *Tabanus*; from South Africa.

DRESDEN MUSEUM:—724 Curculionidae; from various localities.

Mr. P. R. DUPONT, Director of Agriculture:—2 species of Coccidae attacked by fungus, 7 Anoplura and 50 eggs; from the Seychelles.

Prof. J. C. FAURE, Professor of Entomology:—20 Coleoptera; from South Africa.

FEDERATED MALAY STATES MUSEUM:—323 Coleoptera; from Malaya.

Mr. J. C. M. GARDNER, Systematic Entomologist, Dehra Dun:—1,493 Coleoptera, 154 Psyllidae, and 186 other Rhynchota; from the United Provinces, India.

Mr. F. D. GOLDING, Government Entomologist :—3 *Haematopota*, 15 other Diptera and 3 pupa-cases, 13 Hymenoptera, 84 Coleoptera, 2 Rhynchota, 23 Orthoptera, and 3 Odonata ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—28 Diptera, 50 Hymenoptera, and 31 Lepidoptera ; from the Punjab, India.

Miss L. F. GRAHAM :—63 Parasitic Hymenoptera ; from Australia.

Prof. G. GRANDI :—1 Chalcid ; from Italy.

Mr. W. GREENWOOD :—103 Lepidoptera ; from the Fiji Islands.

Mr. F. C. HADDEN :—196 Curculionidae ; from the Philippine Islands.

Mr. G. J. HAEUSSLER :—22 Parasitic Hymenoptera ; from France.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—13 Culicidae, 3 *Tabanus*, 5 *Stomoxys*, 379 other Diptera, 600 Parasitic Hymenoptera, 82 Coleoptera, 132 Lepidoptera, 2 species of Coccidae, 2 species of Aphidae, 1 species of Aleurodidae, 15 Psyllidae, 153 other Rhynchota, 39 Orthoptera, and 12 Collembola ; from Uganda.

Mr. H. HARGREAVES, Government Entomologist :—6 Diptera ; from Uganda.

Mr. W. V. HARRIS :—4 Formicidae, 14 Coleoptera, 7 Orthoptera attacked by parasites, 150 other Orthoptera, and a number of Mites ; from Tanganyika Territory.

Prof. W. E. HOFFMANN :—445 Coleoptera ; from China.

Mr. G. H. E. HOPKINS, Medical Entomologist :—82 Culicidae and 7 slide preparations, and 21 Parasitic Hymenoptera ; from Uganda.

Dr. J. C. HUTSON, Government Entomologist :—103 Diptera and 28 Coleoptera ; from Ceylon.

INDEPENDENT BIOLOGICAL LABORATORIES, TEL-AVIV :—3 Chalcididae and a Spider ; from Palestine.

INDIAN MUSEUM, CALCUTTA :—2 Coleoptera ; from India.

INSPECTEUR DE LA DÉFENSE DES CULTURES, ALGER :—63 Parasitic Hymenoptera ; from Algeria.

Mr. L. A. L. KING :—38 Parasitic Hymenoptera and 29 cocoons ; from Scotland.

Mr. W. R. S. LADELL :—2 Parasitic Hymenopterous cocoon masses, 4 Lepidoptera and 2 pupa-cases, and 18 Trichoptera ; from Siam.

Dr. W. A. LAMBORN, Medical Entomologist :—A number of Mites and 6 Nematodes ; from Nyasaland.

Mr. O. B. LEAN, Assistant Entomologist :—2 Orthoptera ; from Nigeria.

Dr. S. LEEFMANS :—114 Lepidoptera, 3 species of Coccidae, and 11 other Rhynchota ; from Java.

Mr. D. De LEON :—64 Parasitic Hymenoptera ; from France.

Mr. R. A. LEVER :—7 Diptera, 4 Parasitic Hymenoptera, 18 Coleoptera, 1 species of Coccidae, and 6 other Rhynchota ; from the Fiji Islands.

Mr. T. L. McCLELLAND :—2 Coleoptera and 2 species of Coccidae ; from Kenya Colony.

Mr. F. J. MEGGITT :—41 Tabanidae, 2 Hymenoptera, 2 Coleoptera, and 3 Ticks ; from Burma.

Dr. D. MILLER, Cawthron Institute :—23 Parasitic Hymenoptera and 11 cocoons ; from New Zealand.

Mr. J. C. v. d. MEER MOHR :—12 Parasitic Hymenoptera ; from Sumatra.

Mr. H. M. MORRIS, Government Entomologist :—19 Culicidae, 6 Tabanidae, 5 *Stomoxys*, 36 *Phlebotomus*, 2 Simuliidae, 50 Coleoptera, 500 Thysanoptera, 9 species of Aphidae, and 15 other Rhynchota ; from Cyprus.

Mr. J. MUGGERIDGE, Entomologist :—36 Coleoptera ; from New Zealand.

Rev. D. P. MURRAY :—11 Parasitic Hymenoptera ; from the Transvaal.

Mr. G. H. MURRAY, Director of Agriculture :—8 Diptera, 6 Parasitic Hymenoptera, 20 other Hymenoptera, 116 Coleoptera, 14 Lepidoptera, 18 Rhynchota, 19 Orthoptera, and 5 Odonata ; from New Guinea.

Dr. A. A. OGLOBLIN :—12 Parasitic Hymenoptera, 6 Curculionidae, and 6 Rhynchota ; from the Argentine.

Dr. R. H. Le Pelley, Assistant Entomologist :—2 Hippoboscidae, 2 Nycteribiidae, 40 other Diptera and 4 pupa-cases, 1,500 Parasitic Hymenoptera, 5 Coleoptera, 23 Lepidoptera, and 3 cocoons, 50 Thysanoptera, 5 species of Coccidae, 1 species of Aphidae, and 40 other Rhynchota; from Kenya Colony.

Mr. A. Pickles :—4 Parasitic Hymenoptera and 3 Rhynchota ; from Trinidad.

Mr. A. W. J. Pomeroy, Medical Entomologist :—272 Coleoptera, 4 Lepidoptera, and 9 Rhynchota ; from the Gold Coast.

Mr. Y. Ramachandra Rao :—17 Diptera and 2 Coleoptera ; from Baluchistan.

Mr. P. Regnier :—2 Orthoptera ; from Morocco.

Dr. A. Reyne :—10 Formicidae and 2 Orthoptera ; from the Dutch East Indies.

Dr. G. Salt :—4 Parasitic Hymenoptera and 11 Lepidoptera ; from Tropical America.

Mr. H. W. Simmonds, Government Entomologist :—7 Tabanidae, 20 other Diptera, 9 Hymenoptera, 49 Coleoptera, 16 Lepidoptera, 1 species of Coccidae, and 3 other Rhynchota ; from the Fiji Islands.

Prof. J. Strohl :—27 Parasitic Hymenoptera ; from Switzerland.

Mr. Sureya Bey :—10 Diptera ; from Turkey.

Mr. A. W. Taylor :—11 Parasitic Hymenoptera ; from Northern Nigeria.

Mr. T. H. C. Taylor :—59 Lepidoptera ; from Fiji and Java.

Mr. I. Thomas :—8 Parasitic Hymenoptera ; from England.

Mr. G. C. Ullyett :—11 Diptera, 61 Parasitic Hymenoptera, and 100 Formicidae ; from South Africa.

Mr. F. W. Urich :—8 Tachinidae, 121 Parasitic Hymenoptera and a number of cocoons, and 33 Lepidoptera ; from the British West Indies.

Mr. R. Veitch, Chief Entomologist :—6 Rhynchota ; from Queensland.

Mr. F. Weber : 3 Coleoptera and 4 early stages ; from Brazil.

Wellcome Tropical Research Laboratories, Khartoum :—350 Diptera, 48 Parasitic Hymenoptera, 4 other Hymenoptera, 54 Coleoptera, 14 Lepidoptera, 69 Dermaptera, and 20 Mites ; from the Sudan.

Mr. H. Wilkinson :—91 Orthoptera ; from Kenya Colony.

Mr. R. H. van Zwaluwenberg :—2 Coleoptera ; from Hawaii.

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